

COVER SHEET

Title of Review:	Analysis of Remediation Alternatives for the Pacific Crossing-1 North and East Submarine Fiber Optic Cables in the Olympic Coast National Marine Sanctuary
Type of Statement:	Environmental Assessment
Lead Agency:	U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA)
Cooperating Agency:	U.S. Army Corps of Engineers, Seattle District
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Action Considered:	Remediation for Shallowly Buried, Unburied, and Suspended Submarine Fiber Optic Cables in the Olympic Coast National Marine Sanctuary
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EXECUTIVE SUMMARY

This Environmental Assessment evaluates alternatives for addressing the existing burial condition of a trans-Pacific fiber optic cable traversing the Olympic Coast National Marine Sanctuary. The cable was laid in 1999-2000. Segments of the cable are not sufficiently buried, and the proposed action is to address this condition (“cable remediation”).

The Olympic Coast National Marine Sanctuary (OCNMS) is a federally designated area of special national significance, recognized for its rich natural resources and human resource values. Site-specific regulations for OCNMS prohibit drilling into, dredging or otherwise altering the seabed of the sanctuary; or constructing, placing or abandoning any structure, material or other matter on the seabed. Submarine cable installation involves substantial seafloor disturbance, and therefore the National Oceanic and Atmospheric Administration’s (NOAA) National Marine Sanctuary Program (NMSP) determined a Special Use Permit and authorization were required.

The U.S. Army Corps of Engineers (ACOE), pursuant to Section 10 of the Rivers and Harbors Act of 1899 has permitting authority for obstructions to navigation, and pursuant to Section 404 of the Clean Water Act has permitting authority for the discharge of dredge or fill material in waters of the United States.

An NMSP permit and an ACOE Section 10/404 permit were obtained for the Pacific Crossing-1 system (PC-1), which includes two cables in Washington State; PC-1 North that links with Japan and PC-1 East that links with Grover Beach, California. In addition, permits and easements from state and local agencies were obtained for installation of the cable.

The two cable routes run parallel across the northern portion of OCNMS, each for approximately 32 nautical miles (52 km) in water depths of 100-330 m. PC-1 cables were installed in OCNMS in 1999 and 2000 following issuance of an NMSP authorization/special use permit, which required the cables to be buried wherever possible, to a target depth of 0.6 to 1.0 m, in order to prevent chronic disturbance to the seafloor and natural resources within the sanctuary, to avoid conflicts with fisheries and exercise of treaty rights of Native American tribes, and to minimize the risk of future cable failure requiring repair and repeated seafloor disturbance. The phrase “wherever possible” acknowledged in the permit that in limited locations the burial depth might not be achieved due to the substrate encountered. The pre-installation seafloor data collected and interpreted by the applicant indicated that the routes selected were suitable for burial using the proposed equipment.

Cable burial to ≥ 0.6 m is the primary method used to protect cables from external aggressions in continental shelf areas to 1000 m depth; it was an industry standard identified by Pacific Crossing Ltd. throughout PC-1 project planning documents and permit application. Cable burial to ≥ 0.6 m depth was critical to issuance of the NMSP permit.

Surveys of the PC-1 cables in OCNMS conducted in 2001 revealed that substantial portions of each cable were not buried to ≥ 0.6 m depth, and lengths of cable were unburied and suspended above the seafloor. At a minimum, approximately 16.1 km (31%) of PC-1 North and 15.4 km (28%) of PC-1 East are buried less than 0.6 m below the mean seabed level and are at risk of

external aggression. Video showed that a minimum of 870 m (1.7%) of PC-1 North and 1,513 m (2.8%) of PC-1 East lay on or are suspended above the sediment surface. Some of this unburied and shallow buried cable lies in areas of active fishing. Also, in numerous places the cables are suspended over or around boulders where physical abrasion might cause an operational failure.

Marine geology experts and cable engineers consulting with NOAA concluded that limited pre-installation geophysical characterization of the cable routes in OCNMS, inattention at potential problem areas, and installation technique are responsible for cable burial of <0.6 m depth in OCNMS. NOAA believes that two operational factors led to the extensive areas of shallowly buried, unburied, and suspended cables in OCNMS - high residual tension and plowing speed.

Within OCNMS, the PC-1 routes traverse the usual and accustomed fishing area of the Makah Indian Tribe and a 4-mile portion of the usual and accustomed fishing areas of the Klallam Indian Tribes. The federal government, including NOAA, has the responsibility to safeguard and protect tribal treaty rights that include access to all their usual and accustomed fishing areas. The Makah Indian Tribe engages in an extensive trawl fishery in the area of the cables, and the Makah Tribal Council has expressed to NOAA concerns about the safety of tribal fishers who could snag gear on unburied cables, the loss of gear snagged on the cable, and the loss of access to portions of their fishing grounds due to the risk of entanglement and potential liability for damage to the PC-1 cables.

Based on the current condition of PC-1 cables in OCNMS, visual observations of the cables, reports from tribal and non-tribal commercial fishers, and data and video reviews by cable engineers, marine biologists and marine geologists, NOAA has concluded that:

- 1) installation of PC-1 cables did not achieve the goals and objectives of the NMSP permit;
- 2) cable burial to ≥ 0.6 m depth could have been achieved over substantially larger portions of the same cable routes with the same equipment;
- 3) the primary causes of insufficient burial (burial <0.6 m) were higher than normal residual tension, a higher speed of plowing than conditions warranted, and limited route selection data;
- 4) the condition of PC-1 cables in OCNMS causes persistent damage to sanctuary resources;
- 5) the cables in their current condition are at increased risk of fault, which could cause repeated disturbance to the seafloor associated with cable repair operations;
- 6) unburied and suspended cable are a potentially serious safety risk to fishers employed in bottom contact fisheries; and
- 7) unburied and suspended cables limit access of Native American tribal fishers to portions of their treaty-reserved fishing grounds.

Consistent with the requirements of the National Environmental Policy Act, NOAA is considering amending the NMSP permit or issuing a new permit to address the condition of the PC-1 cables. ACOE is considering amending its authorization to allow the proposed remediation to be performed. NOAA's goal is to fully achieve the objectives of the terms and conditions of the Permit, which would prevent chronic damage to resources, substantially reduce the risks to resources and fishers, and restore access of Native Americans to their treaty-reserved fishing grounds. NOAA is evaluating various remedial options to determine which option or combination of options would be most suitable to achieve this goal. The proposed action and

alternatives constitute mitigation measures to address the existing cable condition. The following are the alternatives and remedial options under consideration:

- Alternative 1: No Action. Under Alternative 1, the PC-1 cables would remain in their current condition, with multiple sections of shallowly buried, unburied, and suspended cable in OCNMS.
- Alternative 2: Reduction of Selected Suspensions Without Splicing. Under Alternative 2, cable condition would be analyzed to identify areas of suspension that have the greatest potential for user conflicts or highest probability of cable fault, based on substrate on which the cable rests and length and height of suspensions. Remediation operations would be focused at a limited number of sites.
- Alternative 3: Protective Rock Cover. A protective cover of rock would be provided wherever cables are shallowly buried, unburied or suspended to reduce or eliminate the risk of external aggression to the cables. Use of this alternative would be limited by factors such as seabed conditions.
- Alternative 4: Repair by Splicing and Cable Retroburial. Remedial actions under Alternative 4 attempt to alleviate suspensions and unburied sections and improve burial depth of the PC-1 cables by inserting sections of new cable to reduce cable tension. In areas where sediments are not conducive to cable burial, cables might be re-routed or replaced with heavier armored cable that would remain unburied on the seabed.
- Alternative 5: Repair of Large Problem Areas. Identified problem areas are clustered into three major sections of each PC-1 cable where cable protection is compromised by shallow burial depth and cable suspension over boulders. Remedial operations at these areas include recovery of existing cables, reinstallation with plow burial to $\geq 0.6\text{m}$ and retro-burial by ROV jetting at bights. Modifications to the existing cable routes could be recommended to optimize burial to $\geq 0.6\text{ m}$ depth.
- Alternative 6: Complete Recovery and Reinstallation with Cable Burial. This is NOAA's Preferred Alternative and ACOE's Proposed Alternative and would include complete recovery of existing PC-1 cables and reinstallation to ensure cable burial to $\geq 0.6\text{ m}$ depth. The existing cable routes could be modified to facilitate burial within OCNMS.
- Alternative 7: Complete Recovery and Reinstallation with Surface-Laid Cable. Alternative 7 is the complete recovery of the existing PC-1 cables in OCNMS and reinstallation of a surface-laid, heavier armored cable on the seabed along a similar route.
- Alternative 8: Management Actions Until Fault, then Complete Recovery and Reinstallation with Cable Burial. Under Alternative 8, PC-1 cables would be left in their present condition until a fault occurs. When a repair is required to either cable system, PC-1 North or PC-1 East, remedial operations are instigated, and both cable

systems within OCNMS are recovered and replaced with buried cable as described in Alternative 6.

Several of the alternatives could be used in combination with one another, specifically Alternatives 2, 3, 4, 5 and 8.

Under alternatives 1, 2, and 8 the cables remain suspended, unburied, and shallowly buried in many areas and would cause persistent disturbance to the sanctuary seafloor and impacts to natural resources. Leaving the cables in this status does not meet the terms and conditions of the NMSP permit. In this condition, the cables are at increased risk of fault, which could result in future seafloor disturbance during repair and reburial operations. In addition, unburied and suspended cables could cause more than a de minimis impact to Makah's treaty right of access to usual and accustomed fishing grounds. Unburied cable also presents a safety risk to all trawlers and also causes area-use conflicts with non-tribal bottom contact fishers. For these reasons none of these alternatives were selected as the preferred alternative.

Alternative 3 (Protective Rock Cover) would require extensive route analysis for evaluation of feasibility and effectiveness for long-term protection. Rock dumping would alter seafloor habitat in a manner inconsistent with sanctuary regulations, by adding a new substrate and by potentially causing further changes to the seafloor from the winnowing of fine sediments adjacent to the rock berm. By itself, this alternative would not meet the terms and conditions of the NMSP permit. Alternative 3 would be used best in conjunction with other alternatives. For these reasons, this alternative was not selected as the preferred alternative.

Alternative 4 (Repair by Splicing and Cable Retroburial) is impracticable to implement due to the considerable number of splices necessary to address the multiple, widespread problem areas along the cable routes.

Alternative 7 (Complete recovery and Reinstallation with Surface-Laid Cable) was not selected because it results in a unburied, heavily armored cable that could be damaged by bottom contact fisheries, presents a safety risk to fishers, infringes on tribal treaty rights, and would cause localized seafloor disturbance along the cable routes.

Alternatives 5 and 6 would allow for planned operations that maximize the probability of cable burial to ≥ 0.6 m depth and minimize persistent seafloor disturbance. These alternatives also minimize the risk of external aggression to the cables and cable faults for the duration of the projected cable life, thereby minimizing the probability of future seafloor disturbance.

Alternative 6 (Complete Recovery and Reinstallation with Cable Burial) was selected over Alternative 5 (Repair of Large Problem Areas) because it provides the highest probability for achieving the objectives of the Permit and for protection of tribal treaty rights, the sanctuary environment, and the future protection of cable from external aggression. Alternative 5 does not address questions that NOAA has related to inaccuracies in cable burial depth where data is lacking; NOAA cannot be certain that areas not addressed by Alternative 5 are buried sufficiently to prevent conflict with fishers. In addition, Alternative 5 introduces more splicing and bights to the existing cable system within OCNMS than Alternative 6, and thus more areas requiring jetting.

Alternatives 2, 3, 4, 5 and 8 could be used in combination with one another; however, due to the limitations indicated above, even combined, none would provide the same level of certainty and reduced risk as Alternative 6.

Alternative 6 (Complete Recovery and Reinstallation with Cable Burial) is NOAA's preferred alternative because it provides the highest probability for achieving the objectives of the Permit and for protection of tribal treaty rights, the sanctuary environment, and the future protection of cable from external aggression.

The cable owner (Pacific Crossing Ltd. or PCL) and the contractor for the cable's original installation (Tyco Telecommunication (US) Inc. or Tyco) have indicated that they will accomplish the cable remediation based on a remediation protocol and plan that would implement NOAA's Preferred Alternative and the ACOE's Proposed Alternative.

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GLOSSARY

ACOE	U.S. Army Corps of Engineers
Bight	a U-shaped loop of cable, typically the location of a final splice, where jetting might be employed for cable burial
External aggression	fault-triggering events caused by third parties and their equipment
Fault	Operational failure of a cable requiring some maintenance or repair. This could be a fiber fault (breakage of glass fibers in the cable), a component fault (failure of an amplifier or splice box), or a shunt fault (see below)
GMSL	Global Marine Systems Ltd.
LWA	Light wire armor (cable)
MSSD	Mid-shelf silt deposit
nmi	Nautical miles (equivalent to 6,076 feet, 1.15 statute miles, or 1.85 kilometers)
NEPA	National Environmental Policy Act
NMSP	National Marine Sanctuary Program
NOAA	National Oceanic and Atmospheric Administration
NPTS	Nominal permanent tension strength - the maximum tension that can be applied permanently in a cable without compromising fiber life expectancy.
NTM	Notice to Mariners
OCNMS	Olympic Coast National Marine Sanctuary
PC-1	Pacific Crossing-1 fiber optic cable system
PCL	Pacific Crossing, Limited, the NMSP permit holder
PLIB	Post Lay Inspection and Burial. Operations conducted after plow cable installation at cable fly over areas and one plow off bottom site to bury cable by jetting and inspect cable burial status.
RCBAR	Revised Cable Burial Assessment Report (ERM 2002)
Residual Tension	Tension that the cable will retain after installation, until disturbed or redistributed by an external force
Shunt Fault	A shunt fault occurs when the copper sheathing that conducts electrical power of the system is exposed to seawater causing a loss or reduction in the cable system electrical power supply, which is ‘shunted’ or redirected from the system to ground. A shunt fault reduces or eliminates the re-transmission of the light waves and degrades or renders the telecommunication system inoperable.
Tyco	Tyco Telecommunications (US) Inc. (and its predecessor at the time of installation, Tyco Submarine Systems, Ltd.), the ACOE permit holder and PCL contractor.
U&A	Usual and Accustomed Grounds of Native American Tribes reserved in treaties established with the U.S. government.
Unburied cable	Cable visible on or above the sediment surface regardless of cable position relative to a trench or the surrounding seafloor

1.0 PURPOSE AND NEED

NOAA's purpose is to determine the actions necessary for the permittee, Pacific Crossing Ltd. (PCL), to meet the objectives of the National Marine Sanctuary Program (NMSP) permit and the Finding of No Significant Impact (FONSI) determination of the Supplemental Environmental Assessment (SEA 1999) developed prior to issuance of an NMSP permit. This action would prevent chronic damage to natural resources, substantially reduce the risks to resources and the safety of fishers, and restore access of Native Americans to their treaty-reserved fishing grounds. This document represents a National Environmental Policy Act (NEPA) review and analysis of remediation alternatives to resolve problems resulting from the installation of the two PC-1 submarine cables in the Olympic Coast National Marine Sanctuary (OCNMS or sanctuary) in 1999 and 2000.

The sanctuary is a federally designated area of special national significance. Regulations for the sanctuary require careful review of proposals for potentially harmful activities and prohibit altering the seabed of the sanctuary; or constructing or placing any structure on the seabed of the sanctuary (15 CFR Part 922, Subpart O). Therefore, an NMSP permit was required for the PC-1 cables to be installed in OCNMS. A SEA (1999) prepared in advance of permit issuance concluded in a FONSI determination based on the feasibility of long-term cable and natural resource protection through cable burial in sediments and expectations of a single disturbance event along a narrow corridor of the sanctuary. Also, the federal government has a legal and fiduciary responsibility to protect treaty rights guaranteed to Native American tribes, including access to all their usual and accustomed (U&A) fishing grounds, as well as a need to protect multiple use of the sanctuary. Cable burial to a depth below which fishing gear penetrates provided a means to address both NOAA's fiduciary responsibility and continued multiple uses of the sanctuary. Because no significant, long-term impacts to the sanctuary environment were anticipated following the initial disturbance from cable installation and, if installed as proposed, the cables would not have interfered with tribal treaty rights, a NMSP authorization/special use permit (Permit Number OCNMS-01-99; hereafter referred to as the Permit) and an ACOE Permit (#1998-2-002042) were issued. The U.S. Army Corps of Engineers, pursuant to Section 10 of the Rivers and Harbors Act of 1899 has permitting authority for obstructions to navigation, and pursuant to Section 404 of the Clean Water Act has permitting authority for the discharge of dredge or fill material in waters of the United States. These permits required the cables to be buried wherever possible in order to prevent chronic disturbance to the seafloor and natural resources within the sanctuary, to avoid conflicts with bottom contact fisheries, including tribal fishers, who use the area, and to minimize the risk of cable failure requiring repair and further seafloor disturbance. Surveys of the PC-1 cables following installation revealed that considerable portions of each cable were not buried to ≥ 0.6 m depth, and considerable lengths of cable were unburied and suspended above the seafloor.

In their current condition, NOAA has concluded that the PC-1 cables fail to achieve the objectives of the NMSP permit conditions. Unburied, suspended and shallowly buried cables cause persistent disturbance to the seafloor, are not adequately protected from external aggression, and are at elevated risk of fault, the repair of which would cause future disturbance to the seafloor and natural resources. Moreover, unburied and suspended cables present a safety risk and area use conflict with bottom contact fisheries and with Tribal treaty fishing rights.

This document reviews a range of remediation options that would achieve the primary objectives of Permit terms and conditions. For the purposes of this document, it is assumed that the cables would remain in OCNMS along or near the existing PC-1 routes. Because the remediation options under consideration are beyond the scope of the existing Permit, including the no action alternative, NOAA anticipates the need to amend the Permit or to issue a new permit to allow remedial actions and mitigation measures. This Environmental Assessment (EA) evaluates the impacts of the different remediation alternatives and the mitigation measures necessary for each, and as such, constitutes the NEPA document necessary prior to issuance of a new or amended permit. NEPA is therefore being used for deciding what activities to allow under the new or amended permit that best address the objectives of the original Permit and FONSI determination.

In evaluation of the possible remedial actions on the PC-1 cables, the primary goals of NOAA are to achieve the objectives of Permit terms and conditions and to minimize the uncertainties associated with remedial actions. In more detail, these goals are to:

1. cause the least long term and repeated disturbance (i.e., during the remaining period for the anticipated 25 year service life of the cables) and damage to sanctuary resources, and reduce the risks of long term disturbance and damage;
2. minimize disturbance and damage to habitat and resources when undertaking a remediation action (i.e., by use of less damaging techniques such as plowing versus jetting);
3. meet the regulatory mandate of OCNMS for protection of natural resources;
4. base the determination on the best available science and understanding of environmental and cable conditions along the cable routes;
5. minimize the safety risks associated with other uses in the vicinity of the cables (primarily fishing);
6. ensure that remedial actions are sufficient to protect tribal treaty rights of access to Usual and Accustomed fishing grounds;
7. develop a strategy that is technically feasible to implement, and maximize the effectiveness of remedial actions;
8. provide accountability for proper execution by the Permit holders;
9. minimize the administrative costs to NOAA associated with monitoring Permit compliance; and
10. develop an approach that is consistent with the legal obligations under applicable laws.

Following this introduction, Section 2 reviews background information on OCNMS, the PC-1 system, and the NMSP permit to PCL. Section 3 introduces various alternative approaches to remediation ranging from no action to complete reinstallation. The affected environment associated with the PC-1 routes in OCNMS is described in Section 4. A current assessment of the PC-1 cables in OCNMS, including burial status, cable condition relative to current bottom contact fisheries, and analysis of risk of cable fault is provided in Section 5, followed by a discussion of the environmental consequences of the cables in their current condition in Section 6. A detailed discussion of remediation alternatives is provided in Section 7. An analysis of the remediation alternatives including identification of NOAA's preferred alternative is presented in Section 8.

2.0 BACKGROUND

This section provides information on the management mandates and authority of the sanctuary, a brief description of the PC-1 system, and planning information associated with permitting the project for installation within the sanctuary.

2.1 Olympic Coast National Marine Sanctuary

OCNMS is one of 13 sites designated in U.S. waters under the authority of the National Marine Sanctuaries Act. OCNMS lies off the northwest coast of Washington State and spans the coast from Koitlah Point, on Cape Flattery at the western end of the Strait of Juan de Fuca, to the Copalis River. The northern sanctuary boundary follows the international border with Canada to where it intersects the 100-fathom (approximately 185 m) isobath, approximately 46 miles (40 nautical miles or nmi) west of Cape Flattery (Figure 1). The sanctuary is a federally designated area of special national significance. OCNMS is recognized for its rich natural resources and human resource values, and sanctuary designation ensured that the area was given specific protection. The overriding objective of the sanctuary is to provide a comprehensive ecosystem-wide approach to natural and historical resource management and protection; its highest priority management goal is protection of the marine environment, resources, and qualities of the sanctuary (NOAA 1993). OCNMS regulations require careful review of proposals for potentially harmful activities and prohibit, or in some manner regulate, the conduct of certain specific activities (15 CFR § 922.152). The prohibited activities directly related to the PC-1 cable system are found at § 922.152(a)(4): drilling into, dredging or otherwise altering the seabed of the sanctuary; or constructing, placing or abandoning any structure, material or other matter on the seabed of the sanctuary, except as an incidental result of several identified activities that do not include submarine cable installation. Furthermore, as a federal agency, NOAA has a fiduciary responsibility to safeguard and protect treaty rights of the Native American tribes and to consider the impacts of proposed activities on the tribes (see Section 4.4.1). As a result, a permit was required for the PC-1 cables to be installed in OCNMS. A new or amended permit is now required to remediate unanticipated, ongoing impacts and risks and to avoid significant impacts. These sanctuary mandates and regulations are fundamental considerations for this NEPA analysis.

2.2 Pacific Crossing-1 Project Description and NMSP Permitting

The entire PC-1 system consists of approximately 20,800 km (12,900 miles) of submarine fiber optic cable for telecommunications between the West Coast of the U.S.A. and Japan (Figure 2). Within Washington State, the PC-1 system includes two cables, a north cable (PC-1 North) that links with Japan and an east cable (PC-1 East) that links with a landing site in Grover Beach, California. Both cables traverse the Strait of Juan de Fuca and land at Mukilteo, Washington. Within the sanctuary, the two cables run parallel across the northern portion of OCNMS for approximately 52 km (32 miles) in water depths of 100-330 m (Figure 1). The combined length of the two PC-1 cables within the sanctuary is approximately 105 km (65 miles). The minimum anticipated service life for these cables is 25 years (David Evans and Associates 1999).

Because the proposed project was prohibited by sanctuary regulations, an authorization/special use permit was required from the NMSP for the PC-1 cables. To support evaluation of the permit

request, a Supplemental Environmental Assessment (SEA 1999) was prepared in advance of cable installation specifically to address the affected environment in OCNMS associated with the PC-1 cables. The SEA described one preferred and two alternative routes in or near OCNMS, as well as the affected environment and environmental consequences of the alternate cable routes. The intent of the project proponents was to bury the cable to at least 0.6 m depth through substrate described as primarily gravel, cobble, sand and clay along the preferred route through the sanctuary. Based on cable route survey data collected by the project proponent, the SEA noted that “Within OCNMS sediments have been surveyed and have been found to be suitable for burial.” (p. 6, SEA 1999).

The authorization and permit for this project was issued by NMSP in November 1999 (Authorization of the ACOE permit number 1998-2-02040/Special Use Permit Number OCNMS-01-99), which granted the permit holder (PCL) and its subcontractor for cable installation (Tyco Submarine Systems, Ltd. (Tyco)) permission “to install, maintain, remove, and operate and leave placed within the sanctuary two fiber optic cables.” The Permit contained special conditions associated with cable burial in OCNMS, including condition 2.A.v, which reads:

“Within the Sanctuary, the cables shall be buried wherever possible. Where plow-burial is not possible, ROV burial shall be used. The authorization/special use Permit holder shall seek to bury the cables in sediments to a depth of between 0.6 to 1 meter. Plow-burial shall be undertaken in such a way and at such speeds so as to minimize turbidity. If burial is not possible due to the substrate encountered, the Permit holder shall notify the sanctuary Superintendent and positions shall be provided to fishing groups, OCNMS, NMFS, Coast Survey, and the U.S. Coast Guard at the completion of construction. No blasting shall be allowed in the Sanctuary.”

The phrase “wherever possible” in the Permit acknowledged that in limited locations cable burial might not be achieved due to the substrate conditions. Pre-installation surveys indicated that the substrate along the routes included cobble, gravel, sand, clay, and mixed sediments (C&C Technologies 1999). The SEA, which was based on Pacific Crossing’s application materials and its and its contractors’ reviews of route survey data states “the proposed route has suitable substrate for cable burial along the entire route” (p. 17, SEA 1999). The primary means of burial, a seaplow, would have to be recovered or “flown” (lifted off the seabed) and the cable laid on the surface of the seabed for approximately 500 m either side of two active cable systems that intersected the PC-1 cable routes. At these sites, post-lay burial by water pressure jetting techniques using a remotely operated vehicle was planned to bury the cable to the minimum 0.6 m depth. Where burial was not possible, the position of unburied cable was required to be provided to fishing groups and government agencies.

2.2.1 Purpose of Cable Burial

The requirement for cable burial as the primary method of cable protection in water depths less than 1000 m is an industry standard that was identified from the start of project planning in the Desk Study Report, the first document to review the cable routes and recommend requirements for submarine cables proposed for the entire PC-1 cable network (C&C Technologies 1998). In Section 6.4 (Cable Protection), it states, “Cable burial, where feasible, should be considered essential to cable protection... Simultaneous cable burial by plough to a minimum of 1.0 m

should be considered as the primary method” (C&C Technologies 1998). The Final Route Survey Report noted that “the single greatest threat to the integrity of submarine cables is bottom trawling.” (p. 34, C&C Technologies 1999). In reference to the entire PC-1 project, the EA states “The cable route has been selected to avoid as many physical obstacles and environmental constraints as possible” (p. 1, David Evans and Associates 1998), including important fishing grounds, dredge spoil sites, abandoned cables and wrecks, military activity areas, and existing and planned submarine cables. The SEA that stated the objective was “to provide the maximum separation between cables and fishing gear that may penetrate the seabed” (p. 6, SEA 1999). These repeated statements of intent and need to bury the PC-1 fiber optic cables in OCNMS emphasize the importance of cable burial for minimization of risk to the cables from physical aggression.

The type of cable selected for the PC-1 network in coastal shelf areas (light wire armor or LWA) is not designed to withstand persistent suspension and severe external aggression, and it generally is not used where seabed exposure is anticipated (Wilson and June 2002; SCIG 2003). LWA cable is designed to be buried for protection from external aggression. LWA cable was used for the PC-1 system in areas where bottom fishing activity was well documented with the assumption that burial to ≥ 0.6 m was possible and overlying sediment would protect the cables from external aggression by fishing gear and other sources (C&C Technologies 1998, David Evans and Associates 1998, SEA 1999). Furthermore, cable burial would minimize area-use conflicts and ensure access to productive fishing grounds by tribal and non-tribal fishers.

In addition to protection of the cables from external aggression and avoidance of user conflicts, cable burial within OCNMS would minimize, if not eliminate, impacts to the seafloor and the associated biological community subsequent to cable installation. The SEA described effects of cable installation on benthic communities as a one-time and highly localized disturbance associated with route clearing, installation plowing, and post-lay burial operations (SEA 1999). The “temporary construction area” was defined as the full width between the skids of the seaplow, or 5.8 m (19 feet) (p. 6, SEA 1999), although most impacts were predicted to occur in a path about 1 m wide where the plowshare creates a trench and appreciably disturbs the sediment. The SEA predicted that some mobile fauna might avoid damage from project equipment, but benthic infaunal organisms that reside within the upper sediment layers would be killed in a limited area. Predicted mortality and organism loss would be caused by burial, smothering from oxygen depletion, excessive turbidity, physical injury, dispersal, or altered habitat. Essentially, the plow would create a temporary impact area with disrupted sediment stratigraphy and some mortality of resident organisms. Following cable installation, recovery of the seafloor was anticipated. The Permit included a provision for the cable owner to fund surveys by OCNMS for a period of ten years that were designed to monitor the recovery of seafloor habitat and communities along the cable routes within OCNMS. This monitoring has provided observations of the cable route and associated off-route control areas. Data analysis is underway and preliminary results indicate that the habitats and communities have not yet recovered, particularly in the coarse substrates.

With the cables buried beneath and protected by sediment, the probability of future seafloor disturbance for cable repair was predicted to be very low over the 25-year service life (see Section 5.6). The SEA stated “There is only a 1.5% chance that there would be a repair due to submerged plant failure within the sanctuary over the entire 25 year design life of the system” (p.

8, SEA 1999). This reliability estimate is based on cumulative component reliability estimates for the entire PC-1 system and means that there might be between 1 and 2 repairs to the cable related to component failure during the 25 year service period (Ken Weiner, Preston, Gates, Ellis, LLP, personal communication 4/16/04). This estimate, however, relates only to component failure in the absence of external aggression and does not reflect the increased risk of cable fault associated with unburied and shallowly buried portions of the cables, as discussed in Section 5.6.

Cable burial also reduces the risk and extent of ongoing disturbance to the seabed from unburied cable. In fact, the Permit included a requirement (Special Condition 2.B.i) that “the ongoing placement and operations shall be conducted in a way that does not destroy, cause the loss of, or injure Sanctuary resources.” As described in Sections 5 and 6, the current condition of PC-1 cables causes continual disturbance to the seafloor, has the potential to harm natural resources, and has an increased risk of fault that will require repair and future seafloor disturbance.

3.0 REMEDIATION ALTERNATIVES

As described further in Sections 5 and 6 below, the current condition of the PC-1 cables in OCNMS, from visual observations of the cables, reports from tribal and commercial fishers, and data and video reviews by cable engineering and marine geology experts have led NOAA to conclude that 1) the PC-1 cables were not installed in a manner that achieves the objectives of the terms and conditions specified in the Permit; 2) the condition of PC-1 cables in OCNMS causes persistent, chronic damage to sanctuary resources; 3) the cables in their current condition are at elevated risk of fault, which could result in further disturbance to the seafloor associated with cable repair operations potentially on repeated occasions during the 25-year service life of the cable system; 4) unburied and suspended cable are a potentially serious safety risk to fishers employed in bottom contact fisheries; and 5) the cables as installed interfere with treaty rights of the Makah Tribe. Based on its analysis and interpretation of information from a variety of sources, NOAA has concluded that action to address problems of the PC-1 cables in OCNMS is necessary to remedy these conditions.

Consistent with the requirements of NEPA, a range of remediation alternatives is considered that represents differing technologies and approaches based on capabilities and limitations of existing submarine cable installation and repair technology. Both individual and combinations of the alternatives below are considered. NOAA’s primary goal is to select the alternative that most fully achieves the objectives of the terms and conditions of the permit. The remediation alternatives reviewed in this document are as follows:

Alternative 1: No Action. Under Alternative 1, the PC-1 cables would remain in their current condition, with multiple sections of shallowly buried, unburied, and suspended cable in OCNMS.

Alternative 2: Reduction of Selected Suspensions Without Splicing. Under Alternative 2, cable condition would be analyzed to identify areas of suspension that have the greatest potential for user conflicts or the highest probability of cable fault, based on location, substrate on which the cable rests, and length and height of suspensions. Remediation operations would be focused at a limited number of sites but would

not involve cable splicing. Following remediation, shallowly buried, unburied and suspended cable would remain in OCNMS with this alternative.

- Alternative 3: Protective Rock Cover. A protective cover of rock would be provided wherever feasible where cables are shallowly buried, unburied or suspended to reduce or eliminate the risk of external aggression to the cables. Use of this alternative would be limited by factors such as seabed conditions (slope) and height of suspension. This alternative involves substantial alternation of the existing habitat if used to its full extent but is also considered for application in combination with other alternatives where rock cover would be used in small areas.
- Alternative 4: Repair by Splicing and Cable Retroburial. Remedial actions under Alternative 4 attempt to alleviate suspensions and unburied sections and improve burial depth of the PC-1 cables by inserting sections of new cable to reduce cable tension. In areas where sediments are not conducive to cable burial, cables might be re-routed or replaced with heavier armored cable that would remain unburied (surface laid) on the seabed. This alternative is limited by the widespread need for splicing and the reduction in cable integrity due to the need for numerous splices. In addition, this alternative does not address shallowly buried cable.
- Alternative 5: Repair of Large Problem Areas. Identified problem areas are clustered into three major sections of each PC-1 cable where cable protection is compromised by shallow burial depth and cable suspension over boulders. Remedial operations at these areas include recovery of existing cables, reinstallation with plow burial to $\geq 0.6\text{m}$ and retro-burial by ROV jetting at bights and other areas of surface laid cable. Modifications to the existing cable routes could be recommended to improve upon the existing route by avoiding steep slopes and boulder patches.
- Alternative 6: Complete Recovery and Reinstallation with Cable Burial. Under Alternative 6, existing PC-1 cables are completely recovered and reinstalled with greater care for route selection, feasibility of cable burial, and installation procedures to ensure burial of the cables to $\geq 0.6\text{m}$ depth. Modifications to the existing cable route could be recommended to improve upon the existing route by avoiding steep slopes and boulder patches. This is NOAA's Preferred Alternative and ACOE's Proposed Alternative.
- Alternative 7: Complete Recovery and Reinstallation with Surface-Laid Cable. Alternative 5 is the complete recovery of the existing PC-1 cables in OCNMS and reinstallation using surface-laid, heavier armored cables on the seabed along similar routes.
- Alternative 8: Management Actions Until Fault, then Complete Recovery and Reinstallation with Cable Burial. Under Alternative 8, PC-1 cables would be left in their present condition until a fault occurs. When a repair is required to either cable system, PC-1 North or PC-1 East, remedial operations are initiated, and the both cable systems within OCNMS are recovered and replaced with buried cable (as under Alternative 6). Shallow, unburied and suspended cable would remain in the sanctuary until the time of a repair.

For each remediation alternative, this document provides a summary of the alternative and a description of the technical methodology, discusses environmental consequences and socio-economic impacts, estimates the area affected, and reviews engineering risks and uncertainties. The comparative risks and benefits of remediation alternatives are summarized in Table 2.

Another approach to reduce the risk to human life, fishing gear, and integrity of the cables would be to implement management measures without conducting work to modify cable condition. Such management measures could include establishment of a fishers' cable organization, implementation of a no-trawl area(s), and/or financial compensation to fishers for loss of area use. Although some of these measures could be recommended in association with other remediation alternatives presented, NOAA concludes that this approach would not achieve the objectives of Permit conditions for resource protection, would allow ongoing damages to continue, and would not achieve the goals outlined in Section 1 of this document.

NOAA considered the alternative of requiring the permittee to permanently remove the cables however, NOAA has previously determined that properly installed cables can be permitted within the sanctuary. Permanent removal would not meet the permittee's purpose and need for the original cable installation. This analysis is therefore focused on a consideration of alternatives to ensure that the cables can remain in the sanctuary in compliance with the permit and in a manner that minimizes or eliminates impacts on sanctuary resources, qualities, values, and users.

4.0 AFFECTED ENVIRONMENT

The following sections address the geology, oceanography, seafloor habitats, biological communities and cultural resources along the PC-1 cable routes in OCNMS. In addition, treaty rights of Native American tribes and responsibility of the federal government to the tribes are discussed. A brief review of the sanctuary's boundaries, management objectives, and regulatory authority relevant to the PC-1 project is provided in Section 2.1. Broad descriptions of the sanctuary environment were provided in the FEIS (NOAA 1993) and the SEA (1999). More detailed descriptions of the area's oceanography, geology, seafloor habitats and biological communities are provided below.

4.1 Geophysical Overview of the Cable Route

Preliminary route assessment geophysical studies were provided in the Final Route Survey Report (C&C Technologies 1999). The OCNMS area was assessed by C&C Technologies for PCL during a "Shallow Water Survey" that covered the cable route in Washington waters at depths between 20-1000 m, during which acoustic and bottom core data were collected to locate and identify potential hazards and sediment characteristics along the proposed cables, and to identify a preferred route that avoided obstructions to cable burial. This survey characterized the seafloor along the proposed cable route within OCNMS using precision swath bathymetry (multibeam), side-scan sonar reflectivity, and sub-bottom profiling for subsurface sediment determination. The acoustic surveys identified a possible shipwreck and 5 prominent rocks or boulders measuring several meters in width and height near the proposed cable route in the sanctuary (C&C Technologies 1999, Appendix IV). The survey included core samples, 10 of

which were collected along the approximately 105 km of cable route within OCNMS. Four cores in the western portion of the sanctuary penetrated only the upper 25 cm or less, which was indicative of hard subsurface material (C&C Technologies 1999). These limited data were used to characterize the geophysical features of the PC-1 cable routes in OCNMS. NOAA's analysis of these survey data identified the following deficiencies: 1) the sub-bottom profile technique used during the route survey proved to be a poor choice for the study area because there was no or minimal acoustic penetration of subsurface layers over much of the cable routes; 2) cone penetrometer testing was not used during the pre-lay geotechnical surveys, although it is a standard and effective technique used to characterize soil stratigraphy commonly employed in combination with acoustic sub-bottom profiling (Allan and Comrie 20001, Jonkergouw 2001); and 3) pre-lay sidescan sonar imagery was collected at a resolution that was unable to detect boulder concentrations that impacted the operation of the plow.

Portions of the Final Route Survey Report that summarized geomorphology on the proposed routes within OCNMS were incorporated in the SEA as Appendix F (SEA 1999). Over 99% of the cable routes traversed areas where the seafloor was characterized as clay, sand, gravel, cobble, and mixed sediments, all unconsolidated soil types. Several areas are noted as having rock outcrops, solid rock, conglomerate of large cobbles/stones, sand waves, steep slopes (e.g., >10° gradient), or evidence of surface layer erosion. Although coordinates were not provided for these features, their locations relative to the proposed cable routes were noted in many instances, and they were not identified as being directly on the preferred routes. The preferred cable route presumably was selected to avoid features that could have prohibited cable burial because 1) the purpose of the survey was "selection of final routes that allow for cable burial in water depths of less than 1000 meters" (p. 1, C&C Technologies 1999); 2) burial is the sole means of cable protection from external aggression when LWA cable is used; and 3) the permit application and SEA indicated that cable burial was anticipated within OCNMS.

4.2 Bottom Oceanography Near the Cable Route

After the PC-1 cables had been installed, Greene and Watt (2002) completed a review of physical oceanography and sedimentology near the cable route through the northern portion of OCNMS. Oceanographic and sedimentary depositional conditions found in this area today were most likely established following a series of sea level transgressions and regressions that resulted in the current sea level, established approximately 5,500 years ago. Glacial and post-glacial sediment were deposited by retreating glaciers (Hewitt and Mosher 2001).

Current day sedimentation on the Washington continental shelf is dominated by contributions from the Columbia River at the southern border of the state. A silt and sand deposit associated with Columbia River sources, termed the mid-shelf silt deposit (MSSD), has peak contributions during winter and spring when Columbia River sediment discharge is highest and the Davidson Current carries deposits northward along the Washington coast. MSSD is thickest and coarsest near the Columbia River and thins considerably near the Strait of Juan de Fuca. Materials of Columbia River origin that reach the northern Washington shelf directly are fine silts. In the northern portion of OCNMS, sediment accumulation rates have been estimated to be minimal, less than 25×10^{-2} gm/cm²/year (Nittrouer 1978). Olympic Peninsula rivers, coastal bluff erosion, and reworking of previously deposited shelf sediment contribute an unknown volume of sediment to the northern sanctuary (Hewitt and Mosher 2001). Greene and Watt (2002)

concluded that sources of sediment near the PC-1 cable routes are scarce, other than existing sediments in the MSSD that may be reworked.

On the Washington coast, a narrow continental shelf with relatively shallow waters tends to focus and enhance the swell energy generated in the Pacific Ocean. Water currents at the seafloor in the northern portion of the sanctuary have been measured and modeled to reach 120 to 150 cm/s, velocities that are capable of transporting sand particles and small pebbles (Foreman et al. 2000, Bornhold 2003b). Severe winter storm waves are powerful enough to transport silt, sand, and pebble-sized sediment on the continental shelf. Gravel and sand are highly mobile in some areas, affected by high-amplitude, long swell and tidal currents (Sternberg and Larsen 1976, Yorath et al. 1979). Sand waves are a bedform feature indicative of mobile sediments that were noted in three settings: 1) in deep troughs (e.g., Juan de Fuca Canyon) with water depths ranging from 230 to 330 m; 2) along edges of prominent shallow banks with water depths of 165 to 200 m; and 3) on shallow bank tops in water depths of 100 to 125 m (Figure 3) (Bornhold 2003b). Along the PC-1 route, the third setting occurs at the western portion of the cable routes. In other areas on the cable route in OCNMS, a combination of tidal currents and wave energy have winnowed the fine-grained sand and silt deposits, leaving lag deposits of fractured boulders, gravel, cobbles, and pebbles in areas and fine grained deposits in other areas (Greene and Watt 2002). As discussed in Section 5.2, movement of surface sediments can alter cable burial depth and the degree of protection provided a cable by overlying sediment.

4.3 Benthic Habitats and Communities Near the Cable Route

General descriptions of the benthic (sea bottom) habitats and communities near the cable route were included in three documents prepared prior to cable installation:

- the FEIS/Management Plan (NOAA 1993);
- the Environmental Assessment for the PC-1 cables (David Evans and Associates 1998); and
- the Supplemental Environmental Assessment for the PC-1 cables (SEA 1999).

These documents describe OCNMS in broad terms as an area of high biological productivity with abundant floral and faunal communities. The absence of detailed information in these documents is characteristic of the paucity of data on benthic habitats and communities in the sanctuary at the time these documents were developed. Most information is centered on fish and shellfish of commercial importance and discussion of impacts to species listed under the Endangered Species Act. NOAA (1993) relates subtidal substrate to habitat type (i.e., rocky, mud, muddy sand, and sand), as defined by Proctor et al. (1980), and provides a habitat description and short list of characteristic fauna. The entire route in the sanctuary for PC-1 cables occurs in the non-vegetated pelagic zone at water depths between 100-330 m. The FEIS also includes lists of species inhabiting each habitat type grouped by trophic level.

Recent surveys conducted by OCNMS have contributed much detail to the information on benthic or seafloor communities, as summarized below. Invertebrate data consists of information obtained from bottom samples collected in the vicinity of the cables but not on the cable disturbance area during OCNMS cruises conducted in 2000 and 2001. The bottom samples primarily represent numerically dominant species of infauna – those organisms living within the

sediment, although epifauna (organisms living on the sediment surface) that are sessile (attached) or with limited mobility can also be captured in a bottom grab sample. For example, brittle stars can be captured in bottom samples. In addition, the primary organisms in video from the cable route are discussed in order to provide a more thorough representation of the epifauna of the area.

The sediment type along the cable corridor was categorized by OCNMS and associated species identified to further delineate the distribution of the invertebrate populations. The sediment type has been divided into several categories based on OCNMS' review of side-scan sonar data collected for PCL or its contractors in 1999 and 2001 and grain size analysis from bottom samples collected by OCNMS. For this assessment, the categories used follow from coarse to fine sediment type:

- gravel-pebble-cobble-boulder
- sand
- silt-clay (mud)

4.3.1 Gravel-Pebble-Cobble-Boulder Substrate

The community description for this substrate is limited due to the difficulty in collecting bottom samples in rocky habitat. This substrate is dominated by the mollusks *Axinopsida serricata*, *Lepidozonia* and *Ischnochiton*, the cnidarian *Anthopleura artemisia*, the crustacean *Eualus pusiulus*, brittle stars *Ophiura sarsii* and *Amphiopholis spp.*, and the polychaetes *Pholoides asperus* and *Galathowenia oculata*.

From the video review of this substrate type, there are many other epifaunal species. Some of the more common include urchins (*Allocentrotus* and *Stronglyocentrotus pallidus*) and seastars (e.g., *Orthasterias koehleri* and *Stylasterias forreri*), the bryozoan *Myriozoum*, the hydrocorals *Allopora* and *Stylaster*, the basketstar *Gorgonocephalus eucnemis*, the squat lobster *Munida* and various sponges (primarily *Heterochone calyx*) and hydroids. A variety of flatfish, rockfish and shrimp are also present in this habitat.

4.3.2 Sand Substrate

Sand substrate represents one of the dominant substrate types in the northern portion of the sanctuary where the PC-1 cable route is located. This substrate is dominated by one of the polychaetes also found in coarser substrates, *Galathowenia oculata* but also *Spiophanes berkeleyorum*. Dominant taxa also include the brittle star *Ophiura sarsii*, several amphipods, including *Ampelisca* and *Rhepoxynius spp.*, Nyantheaen cnidarians, and the mollusk *Axinopsida serricata*.

Many of the species seen in videos of the gravel-pebble-cobble-boulder substrate are also found in sand substrates, although in fewer numbers, such as the urchins *Allocentrotus* and *Stronglyocentrolus pallidus*, the brittle star *Ophiura sarsii*, the polychaete *Galathowenia oculata*. Several seastars, flatfish and shrimp are common in these areas.

4.3.3 Silt-Clay (Mud) Substrate

This finer, soft substrate is also one of the predominant substrates in the northern part of the sanctuary. It is dominated by polychaetes, molluscs and brittle stars. Once again, the polychaete *Galathowenia oculata* dominates the community but also *Spiophanes berkeleyorum*. The dominant brittle star is *Ophiura sarsii*. Calanoid copepods and the bivalve *Macoma carlottensis* are abundant. Sipunculids are also common in these softer substrates as are cnidarians in the suborder Nyantheae.

The epifaunal species seen on the video of the silt-clay habitat are similar to those seen in the sand habitat, although there is a greater abundance of brittle stars, flatfish, and burrowing organisms.

4.4 Social and Economic Environment

4.4.1 Native American Tribes and Treaty Rights

In the mid-1850's, the United States government entered into treaties with a number of Indian tribes in Washington that reserved and guaranteed the signatory tribes the right to fish at U&A grounds. The Treaty of Neah Bay was signed by representatives of the Makah Tribe and U.S. federal government in 1855. The Makah Indian Reservation at Cape Flattery lies at the northwest corner of Washington State (Figure 1) where tribal land ownership extends from uplands areas to mean-lower-low water on the shore. Tribal treaty rights, however, extend well beyond tribal reservation boundaries to include marine areas within U&A fishing grounds. Within their U&A grounds, each tribe shares management responsibility for natural resources with state and federal agencies. Tribal interests in and co-management authority over exploitable natural resources are an essential consideration in any action that affects the natural environment. The Makah U&A grounds include waters of the western Strait of Juan de Fuca and off the Washington coast from Cape Flattery, south for approximately 23 miles and up to 40 miles offshore. The three Klallam Tribes (Elwha, Jamestown, and Port Gamble) have U&A fishing grounds in the Strait of Juan de Fuca that extend westward to Cape Flattery. All these tribal U&A grounds extend north to the international boundary. PC-1 cable routes are within Makah and Klallam U&A grounds in the Strait of Juan de Fuca. At the western Strait of Juan de Fuca, the PC-1 routes traverse 4.6 miles where the Klallam U&A grounds and OCNMS overlap. West of Cape Flattery, the PC-1 cable routes are within the U&A fishing grounds of the Makah Tribe. The entire length of both PC-1 cable routes within OCNMS, or approximately 105 km (65 miles) total for both cables, is in the Makah U&A grounds.

Makah tribal members currently have about 14 bottom trawl vessels and 25 long-line fishing vessels, as well as vessels working pelagic, or water column, trawl and purse seine fisheries (Russ Svec, Makah Fisheries Director, personal communication). Each vessel supports a crew of 3-5 people during fishery openings. Commercial fishing is a major, vital and essential element of the economy of the Makah Tribe and Neah Bay community. Any activity or condition that has adverse impacts on the fishery resources in their U&A fishing grounds or limits the area in which fishers can safely operate without risk of snagging or losing gear will impact the Tribe. Tribal fishing rights that were reserved in treaties with the federal government are limited to U&A grounds, and tribal fisheries cannot extend outside of the tribe's U&A grounds. As a result, area

use restrictions on fishing activity within a tribe's U&A grounds disproportionately affect tribal fishers because they do not have the option of shifting effort to areas outside their U&A grounds, unless they obtain a non-treaty commercial license, upon which they must give up their tribal license.

The Federal government has a unique legal and fiduciary relationship with Indian Tribal governments as set forth in the Constitution of the United States, treaties, statutes, Executive Orders, and court decisions. The fiduciary or trust responsibility of federal agencies, including NOAA, to the Makah and other treaty tribes is, in part, articulated in several judicial decisions, sanctuary regulations, and in Executive Order 13175 of November 6, 2000, *Consultation and Coordination With Indian Tribal Governments*. The federal government has a responsibility to safeguard and protect the Tribes' treaty rights, including access to their U&A fishing grounds. Sanctuary regulations (15 FR 922 Subpart 0) require that during evaluation of a permit request for activities within its boundaries, the sanctuary consider the impacts of the activity on Indian Tribes. Consideration of tribal interests is especially important when ruling on permit applications to conduct development activities that might impact natural resources within the sanctuary. The federal government's fiduciary obligation also requires that remedial actions are sufficient to protect the Tribe's treaty right of access to its U&A fishing grounds.

The ACOE permit, that the NMSP authorization for cable installation is based upon, reviewed the proposed PC-1 project and treaty rights, sought comments from tribes and the sanctuary, and concluded that if the cables were installed as specified (i.e., buried to 0.6m to 1.0 m depth) the project would not interfere with access to U&A fishing grounds or with fishing activities (p. 9 ACOE Permit #98-1-02040). This conclusion, and the development of an SEA, led to the NMSP's decision to authorize installation under the ACOE permit and issue a special use permit for operation, maintenance, removal and disposition of the two PC-1 cables in the sanctuary.

Following revelation of PC-1 cable conditions post installation, the Makah Tribal Council reviewed maps of shallowly buried and unburied PC-1 cables and expressed strong concerns about current and future impacts of the cables on Tribal fisheries (Tyler 2003). Specifically, Makah fishers consider that unburied cable poses a serious risk of entanglement for fishing gear and a safety risk to vessels and personal injury. Further, they note that longline fishermen have reported losing gear due to encounters with the cable, and bottom trawlers have reported gear snagged on the cable. Currently, Tribal fishers try to avoid fishing in the general area of the cables, which are normally productive areas for these fisheries. Furthermore, Tribal fishers report that shallowly buried and unburied PC-1 cables, as identified in public notices issued in October 2000 (WDFW 2000) and October 2001 (USCG 2001), create area closures that prevent Tribal fishers from fully accessing their Tribe's U&A fishing grounds. This loss of access to treaty-guaranteed fishing grounds is a direct violation of their treaty with the federal government. Moreover, this area-use restriction reduces the ability of Makah fishers to succeed economically in what has long been a challenging business, one that contributes significantly to the economy of their remote community. Consequently, the Makah have expressed concerns to OCNMS about the condition of the PC-1 cables and have stated their strong desire for remedial actions that result in buried cables throughout the sanctuary to avoid current and potential future conflicts and restrictions on treaty rights (Tyler 2003).

4.4.2 Fishing Activities

In the northern portion of OCNMS, active commercial fisheries that put gear on the seafloor are longline, bottom trawl, and crab, fish, and shrimp pot fisheries. Commercial landings (non-tribal) in the northwest Olympic Peninsula for the two largest components, longline and bottom trawl groundfish fisheries, were about \$6 million in 2001 and 2002, the most recent data that are available. These fisheries have potential to contact and cause external aggression to unburied and suspended sections of PC-1 cables.¹ A brief description of each fishery is provided here, as well as an analysis of recent non-tribal effort in the vicinity of PC-1 cables, in terms of spatial distribution of fishing activity and numbers of vessels and/or trawls.

The longline fishery targets groundfish, such as halibut, sole, rockfish, blackcod, and sablefish. In recent years, the longline fishery has targeted depths from about 100 m to beyond 1000 m (NRC 1994). Vessels participating in this fishery in OCNMS generally range from about 9.2 to 15.4 m (30 feet to 50 feet) in length, with gross tonnage from about 14 to 40 tons. Longline gear can stretch across several miles of seafloor and is composed of a groundline with a thousand or more large hooks on short leader lines, terminal anchors, and lines to surface buoys (Figure 4). Terminal anchors are typically metal hooks or two pronged kedge anchors weighing roughly 10 to 20 pounds that dig 0.1-0.3 m into seafloor sediments where they can snag shallowly buried or unburied cables. Although the breaking strength of the gear is low and hooked gear could not cause a substantial pull on a submarine cable, hooks and anchors from longline gear can snag, penetrate or damage the polyethylene insulant of fiber optic cables thereby increasing the potential for a 'shunt' fault (see Section 5.6.2). The halibut fishery targets sand and gravel bottom, while the sablefish longline effort is located on mud bottom on the outer continental shelf edge (NRC 1994). Because longline fishers are not required to participate in the logbook reporting program in Washington State, it is difficult to estimate the number of gear sets and distribution of longline effort off the Washington coast. However, interviews with longline fishers indicate that a broad area of the outer continental shelf off Cape Flattery is fished each year (Figure 5). An estimated 32 vessels in 2001 and 44 vessels in 2002 participated in the longline fishery in OCNMS, based on reported landings for the limited entry sablefish longline fishery north of Point Chehalis/Westport, Washington (Brian Culver, Washington Department of Fish and Wildlife, personal communication). Many of the same vessels also participate in the halibut longline fishery.

About 30 groundfish trawler vessels have fished in the vicinity of the PC-1 cables in OCNMS in recent years, with a most active trawl fleet of 12 to 15 vessels that work the area on a regular basis. Most groundfish trawlers that work the northern sanctuary are between 12 and 18 m (40 and 60 feet) in length and 40 and 90 gross tonnage, with 300 horsepower engines. The larger vessels in the fleet exceed 30 m (100 feet) in length and 200 in gross tonnage. Typical groundfish trawl gear used off Washington has several components that contact the seafloor: a footrope along the bottom leading edge of the net, short "tickler" chains on the footrope that scare fish off soft bottom, small oval rubber disks to assist gear drag across harder bottoms, wire rope bridles

¹ In this document, unburied cable refers to cable visible on or above the sediment surface including cable that is visible in an unfilled trench. An unburied cable can be hit or snagged by fishing gear. Buried cable, as defined in RCBAR, refers to cable that has sediment on top of it, whether it is a thin layer or a meter thick.

that connect the wings of the net to the otter doors, and two large, metal otter doors, each weighing between 600 to 2,000 pounds each (Figure 6) (NRC 1994, ERM 2002). Even on smaller trawl vessels (those less than 100 feet or 30.8 m long), otter doors are heavy, welded, thick steel plates, the smallest of which measure roughly 3 feet wide, 5 feet tall, and 4-6 inches thick (Figure 7). Under tow, these heavy metal doors normally ride upright across the seafloor and typically penetrate the sediment surface. The bridles and tow wires are typically ¾ inch steel cable with a breaking strength of 29.4 short tons (58,800 pounds) and a working load of about 6 short tons (12,000 pounds). Trawl nets are towed across the seafloor at two to four knots for a duration of 30 minutes to several hours. Experienced trawler captains are familiar with the location of and avoid areas with extremely rough bottom, wrecks, and other obstructions on which gear can snag and be damaged. Off Washington, groundfish trawlers can work areas as deep as 1000 m or more (NRC 1994).

According to reports from captains who fish off the Washington coast, trawl doors typically penetrate approximately 0.13 m (4 to 6 inches) in soft mud, based on visible scouring on the rusted metal shoes welded to the bottom of the trawl doors (Jeff June, NRC, Inc., personal communication). This estimate matches a widely quoted estimate for penetration of trawl doors under tow of 0.15 to 0.3 m (6 to 12 inches) in soft mud and less in firmer sediments (Meggett 1999, Hoshina and Featherstone 2001, CCC 2002). However, maneuvers such as the initial set (bottom contact) of the trawl doors or sharp course alterations on soft ground can cause trawl doors to bury as much as 0.5 m (1.6 feet) (Meggett 1999). As a result, shallowly buried fiber optic cables less than about 0.5 m below the sediment surface are at risk of being hit or snagged by trawl gear (see Section 5.6.2). This level of risk is not static; redistribution and erosion of sediment overlying a fiber optic cable can reduce the sediment cover and increase the risk of fault from such external aggression (see Section 5.2).

Areas of active bottom trawling for mixed groundfish by non-tribal fishers near the PC-1 cables were determined by analysis of the most recent groundfish bottom trawl logbook information, years 1999-2001 (Figure 8). Trawl logbook data include a single geographic position for each tow. Because there is only one position point to represent the entire tow and the direction of travel is not recorded, it is not possible to identify precisely the full course of each trawl or the exact number of trawl tows that traversed the PC-1 cable routes during this period. For this analysis, it was assumed that an average trawl traverses approximately 21 km (15 nmi or 13 miles), based on the average duration and speed of travel. The areas of recent bottom trawl activity indicated in Figure 8 agree well with the four areas along the PC-1 cable routes preferred by bottom trawlers as identified through interviews with fishers (Appendix B, ERM 2002), although the logbook data cover a more expansive area.

Because trawlers typically drag along seafloor contour lines that generally are perpendicular to the PC-1 cable routes, any trawl originating within 21 km of the cable routes potentially could intersect with PC-1 cables. Based on analyses of 1999-2001 trawl logbook data, approximately 2,550 bottom trawl tows by non-tribal vessels were located in the sanctuary where the trawls might have traversed one or both PC-1 cable routes. Because shallowly buried cable (≤ 0.6 m below mean seabed level) is widely distributed along the PC-1 cable routes, all 2,550 trawls could have intersected areas of shallowly buried cable. Similarly, unburied and suspended cable sections are widely distributed, and nearly all trawls conducted in the northern sanctuary, an estimated 2,496 bottom trawl tows, could have traversed areas of unburied or suspended cable

between 1999 and 2001 (Figure 8). On average, 832 trawls per year were conducted by non-tribal vessels in the vicinity of PC-1 cables in recent years and could have contacted unburied and suspended cable in the sanctuary.

This characterization of bottom trawling does not include operations and developments in Makah tribal fisheries, whose data were not available for this analysis and potentially represent over 50% of the current trawling effort near the cables. In years past, salmon have been the dominant economic basis of Makah fisheries. Yet as salmon stocks have declined, Makah commercial fishers have shifted to longline and trawl fisheries to support Neah Bay's economy. At present, there are about 14 tribal vessels that participate in the Makah groundfish trawl fishery. The Makah Tribe is responsible for developing its own fishing regulations based on allocations developed in agreement with the federal government and other tribes. Makah tribal trawlers can fish anywhere within their U&A fishing grounds and anywhere along the PC-1 routes in the sanctuary, subject to Makah tribal fishing regulations. Tribal fishers are not subject to the depth-based closures that constitute the rockfish conservation area off Washington, and they are not restricted from working the area east of Tatoosh Island, an area that is closed to non-tribal vessels, which includes the eastern portions of the PC-1 routes north of Cape Flattery. This is an area of PC-1 East where no reliable data on cable condition are available to assess risk to fishers and the cables. Unfortunately, geographic data for Makah trawlers was not available for this review, and Makah fishing effort is not depicted on any figures in this report. Nevertheless, it is likely that Tribal fishers work similar areas as non-tribal trawlers indicated in Figure 8.

Off Washington, bottom trawl gear is also deployed for pink shrimp. There are about 12 vessels that trawled for pink shrimp off Washington in recent years. Shrimp trawl nets employed off Washington are not allowed to use tickler chains. Most bottom trawling for pink shrimp occurs south of the PC-1 cables. However, based on recent trawl logbook data (1993-1999) from Oregon and information from Washington state groundfish biologists, shrimp trawl fishing effort occurs in the vicinity of the PC-1 cables where sections of unburied and suspended cables are located (Figure 10). Typically, shrimp trawl gear is lightly in contact with the seabed and uses lighter trawl doors than groundfish nets (NRC 1994); therefore, it is possible, yet less likely than groundfish trawl gear, for shrimp trawl gear to damage an unburied cable or to entangle with suspended cable and put the gear, vessel and crew at risk. Abandoned shrimp trawl gear can also contribute to ghost fishing (see Section 6.1). The prawn bottom trawl fishery that used bottom contact gear was recently closed off Washington State, and the possibility of reopening is uncertain.

Pot fisheries use metal frames wrapped with synthetic mesh webbing, and each pot weighs between 75 to 150 pounds, depending on the construction and weight added to sink the gear. Dungeness crab pots are deployed as single buoyed pots, while sablefish pots can be set in strings of several dozen pots that stretch for 1 nmi (1.15 miles) or more along a groundline (NRC 1994). Either single or multiple pots set adjacent to suspended and unburied PC-1 cables can snag the cable during retrieval. Currently there are no sablefish pot fishers that work the northern sanctuary area (Brian Culver, Washington Department of Fish and Wildlife, personal communication). Most crab pot fishing is currently well south of the PC-1 cables (Figure 11). Nevertheless, there may be some effort in the vicinity of the PC-1 cables depending on the distribution of the crab stocks. Crab pots are dragged along the seabed for up to 10 m while being retrieved by the vessel, depending on the depth and the amount of extra float line deployed.

Pot gear has relatively low potential to physically damage fiber optic cables because the gear and lines are relatively light weight. However, a crab pot could snag on unburied and suspended cable and result in loss of the crab pot and subsequent ghost fishing.

4.5 Historical/Archaeological Resources and Known Cultural Artifacts

Under the National Historic Preservation Act of 1976, federal agencies must review all activities to ensure there are not impacts on historic and archaeological properties of the sites. A general description of cultural resources in OCNMS was provided in the SEA (SEA 1999).

Approximately 20 shipwrecks have been documented in the vicinity of the PC-1 cable within OCNMS (Figure 3 in SEA 1999). One probable shipwreck was identified in pre-lay surveys lying 1.1 km north of Segment E (Tyco 2000b). The ship lies in 235 m of water and measures 100 m x 20 m x 10 m. The cable route was revised to avoid this wreck. A subsequent ROV survey was performed in June 2001 to document this wreck, which was identified as the USS Bugara, a submarine that saw active service during World War II and the Korean conflict and sank off Cape Flattery in 1971 while under tow for decommissioning.

5.0 CURRENT ASSESSMENT OF PC-1 CABLES IN OCNMS

At a minimum, 30.2 km of PC-1 cables in OCNMS were not buried to at least 0.6 m and, as such, may be at risk of external aggression from bottom-contact fisheries active in the area now or in the future. In addition, the cables show definite signs of having been installed with higher than normal residual tension, as well as over and around boulders where abrasion can damage the cables. The light-wire armor cable selected for use in OCNMS is normally buried to 0.6 m or deeper in sediments of continental shelf waters to provide protection from such aggressions. Expert geologists found the substrate and seafloor topography along the cable routes to be suitable for burial, with limited exceptions, yet successful cable burial was not achieved over extensive areas in OCNMS. Cable engineering experts concluded that high residual tension applied to the cable during installation (i.e., the installation technique used) was the principal cause for burial of <0.6m depth within the sanctuary, particularly at fly over areas. These topics are discussed in detail below to provide context for consideration of remediation alternatives.

5.1 Cable Burial Status

In November 1999 and February 2000, PC-1 cables (North and East, respectively) were laid in OCNMS. Although Pacific Crossing's contractor, Tyco, reported that the PC-1 cables had been successfully buried on PC-1 N (Tyco 2000a) or "carried out in accordance" with the Permit, with some suspensions at PLIB sites on PC-1 E (Tyco 2000b), subsequent cable assessment surveys by other contractors for Pacific Crossing, and habitat recovery monitoring surveys conducted by NOAA have revealed that considerable portions of the PC-1 cables within the sanctuary are less than 0.6 m below the seabed, unburied on the surface, or suspended above the seafloor. These surveys did not cover the entire cable routes in OCNMS, but approximately 79% of the east route and 93% of the north route were surveyed using a cable tracker system (TSS 350) and video in June 2001 (Table 1). Review of existing cable burial data and video reveals that, at a minimum (because not all of the cable has been surveyed), approximately 16.1 km (31.4%) of PC-1 North and 15.4 km (28.0%) of PC-1 East were not successfully buried at least 0.6 m below the seabed.

These values include a minimum cumulative distance of 2.3 km (1.48 miles) that is visible on or above the sediment surface in OCNMS and poses a hazard to fishers (Table 1). Shallowly buried, unburied, and suspended cable sections are widely distributed along both PC-1 cable routes in OCNMS (Figure 1).

At a minimum, 15.4 km (28.0%) of PC-1 East were not buried ≥ 0.6 m below the seabed. Based on video footage covering approximately 80% of PC-1 East in OCNMS, this cable is visible on or above the sediment surface for a total of 1,513 m (2.8%), including intermittent suspensions, or sections alternately in suspension and on/in the seabed. In total, 98 suspensions were noted on PC-1 East (Appendix J, ERM 2002). For example, video logs indicate that PC-1 East has 19 cable suspensions over 30 m long and 6 suspensions elevated at least 0.5 to 0.6 m above the seafloor (Appendix J, ERM 2002). There are 6 places where video logs indicate the PC-1 East cable is suspended over boulders (Appendix J, ERM 2002). Moreover, these estimates do not incorporate uncertainty associated with data gaps. No cable burial depth data are available to evaluate cable burial depth for approximately 9.6 km (17.4%) of the PC-1 East route in the sanctuary, although video shows buried cable for 6.2 km of this distance. For 2.1 km (3.9%) of PC-1 East, there is no information (neither video nor cable burial depth) to support a reliable assessment of cable condition or burial status (ERM 2002).

At a minimum, 16.1 km (31.4%) of PC-1 North was not buried ≥ 0.6 m below the seabed. Video coverage is available for 93.3% of PC-1 North that shows a cumulative distance of 870 m (1.7%) visible at or above the seabed, with 215 m (0.4%) suspended above the seabed. The Revised Cable Burial Assessment Report (RCBAR) noted 9 cable suspensions on PC-1 North, three of which occur where cable is laid atop boulders (Appendix J, ERM 2002). No cable burial data are available for approximately 3.4 km (6.6%) of PC-1 North, although video shows buried cable for 1.5 km (2.9%) of this. Neither video nor burial depth data are available to assess cable burial status for 3,318 m, or 6.5% of this route (ERM 2002).

Serving damage, or damage to the outer protective layers of the cable, and exposed armor were noted in several places (Tyco 2000b, ERM 2002). Such damage could have occurred during installation as the cable passed through the plow, or it could have happened after installation due to external aggression, such as chafing against rock or contact with trawl gear. Observations of frayed cable serving and exposed metal armoring with a fresh or polished appearance where cable is laid over boulders indicate that physical damage to outer armoring layers of the cables has occurred after installation and that cables may be at risk of fault at these locations (Figure 12, see Section 5.6.1).

Failure to achieve ≥ 0.6 m burial occurred both with plow installation and ROV jetting at PLIB sites. PLIB operations for retroburial of cable using a hydrojet at plow flyover sections account for approximately 3.1 km (5.6%) of PC-1 East and 1.5 km (2.9%) on PC-1 North cables. Average burial depths from the 5 PLIB sites initially were reported as 0.10 m to 0.40 m, with areas of unburied cable and portions of cable buried shallower than 0.1 m (Tyco 2000a and 2000b). Video coverage of PLIB sites is incomplete, but available video indicates about 0.8 km and 0.6 km of unburied and suspended cable occur in PLIB sites on PC-1 East and North,

Table 1. Analysis of cable burial depth and cable condition as interpreted from cable tracking system (TSS 350) and video data ¹

	PC-1 North		PC-1 East	
	<u>Meters</u>	<u>percent of total</u>	<u>meters</u>	<u>percent of total</u>
<u>Depth of Cable Burial (TSS 350 Data Only)</u>				
>0.6 m	31,836	62.0%	29,500	53.7%
≤0.6 m	16,143	31.4%	15,385	28.0%
no data available (data gap)	3,370	6.6%	11,404	20.7%
total length	51,349	100.0%	54,982	100.0%
PLIB only ²	1,490	2.9%	3,074	5.6%
≤0.6 m - plow burial only ³	14,653	28.5%	11,004	20.0%
<u>Video Interpretation of Cable Condition</u>				
total visible on surface or suspended ⁴	870	1.7%	1,513	2.8%
suspended (incl. short, intermittent suspensions)	215	0.4%	1,156	2.1%
cable covered, no TSS data (no burial depth data)	1,494	2.9%	6,249	11.4%
no video or TSS data (data gap) (ERM 2002)	3,318	6.5%	2,132	3.9%

1 Analysis based on data from the electronic database supplied to OCNMS by contractors for PCL.

2 PLIB (post lay inspection and burial) areas subject to hydrojetting for burial, where plow burial was discontinued.

3 Includes shallowly buried, unburied, and suspended cable over areas where plow burial was attempted.

4 Cable without overlying sediment, either within a trench, on the seafloor, or suspended above the seafloor.

respectively. TSS data differs, and it indicates about 1.1 km and 0.4 km of suspended cable at PC-1 East and North PLIB sites, respectively. Cable installation by the plow was unsuccessful in achieving burial >0.6 m for at least one fifth of the PC-1 cable routes in OCNMS, a minimum of 11.0 km (20.0%) of PC-1 East and 14.7 km (28.5%) of PC-1 North. Available video covering about 75% of the routes in OCNMS indicates a minimum of about 0.7 km or PC-1 East and 0.3 km of PC-1 North that are unburied or suspended in areas where plow installation was used. Permit conditions for cable burial to ≥0.6 m wherever possible do not differentiate between jetting and plow burial operations.

5.1.1 Data Limitations

Whereas available data support an assessment of current cable condition and burial depth, major data gaps introduce uncertainty in the assessment and make all estimates of current cable condition minimum values. Achieved depth of cable burial within OCNMS was measured by contractors to Pacific Crossing using a cable tracking device (TSS 350) on two occasions, 1) during PLIB operations covering limited areas at cable crossings, and 2) a June 2001 survey of the majority of the routes. In addition, video footage of unburied and suspended cable was collected during the June 2001 survey. This was supplemented by OCNMS video collected during habitat recovery monitoring surveys in 2000 and 2001 covering relatively small portions of the cable routes. OCNMS did not collect video in 2002, and 2003 data were not available at the time this analysis was completed. Consequently, analyses of cable suspensions, unburied cable, position relative to the plow trench, and locations of boulders were made primarily from video logs in the RCBAR (ERM 2002).

This document's assessment of cable condition differs from the RCBAR because it excludes plow depth data from the analysis because plow depth data collected during installation reflect the instantaneous operation of the plow but may not accurately represent the actual position of the cable as installed relative to the seabed (Appendix K, ERM 2002). Although plow data over a relatively short distance (e.g., 200-300m) might be reasonably used to estimate achieved cable burial depth with careful consideration of associated plow and substrate information, the variability in residual tension values, seafloor slopes, and substrate characteristics that routinely occurred throughout the PC-1 routes in OCNMS make such extrapolation unreliable (Darbyshire 2004). Achieved cable burial depth data used for this document's analysis relies on post installation cable tracking (i.e., TSS 350) data collected during PLIB operations and the June 2001 survey. The accuracy of these data is uncertain, and the existing dataset contains some erroneous values. As discussed in Section 5.6.2, this uncertainty is most critical when evaluating the threat of external aggression to shallowly buried cable. Also, such uncertainty supports a conservative approach to assessment of risk to cable from external aggression, one that favors deeper cable burial over shallow burial.

5.2 Changes to Cable Burial Anticipated Over Time

Changes to cable burial depth, both increases or decreases, could result from several factors, including deposition of sediment from overlying waters, redistribution of existing seabed sediments, movement of berm material to fill the existing plow trench, and increased tension or pull on a cable from marine equipment (e.g., trawl and longline fishing gear, grapnels, anchors). Greene and Watt (2002) concluded that sources of sediment to the areas of cable installation are scarce, other than redistributed seabed sediments. As a result, gradual burial of exposed cable or an increase in burial depth over time is not likely to occur from new material deposited from the water column. Because the PC-1 cables are under greater than normal installation tension and, in places, suspended above the seafloor and subject to strumming or vibration, it is unlikely that natural sediment deposits will eventually cover the cable (Greene and Watt 2002). Trawl gear can erode sediment on down slopes of plateaus and expose cable (Appendix B, ERM 2002).

The dynamic nature of seabed sediment can result in localized changes to cable burial conditions over time. The mobility of seafloor sediments is evidenced by the presence of sand waves that

were seen in water depths ranging from about 110 m to 330 m (see Section 4.2). These features were found in a variety of forms, including small ripples, megaripples (e.g., 0.4 to 1.5 m high and >1-2 m wavelength), and sand waves (>1.5 m high), and could be produced by both tidal currents and surface long-period swell associated with storms (Bornhold 2003b). Such features were found at several locations, primarily in the western half of the cable routes in OCNMS, and they covered <5% of each cable route (Figure 3). One solitary sand wave 15 m high with an adjacent deep trough was found on the western portion of PC-1 North (Bornhold 2003b). Sand waves tend to migrate across the seafloor over months and years, which will lead to changes in the burial depth of the cables. This potential for erosion of overlying sediment is a component of the justification for a safety factor, or setting the target cable burial depth beyond the known penetration depth of fishing gear and anchors (Allan 1998).

Concern for redistribution of seafloor sediments causing changes in cable burial status is justified. For example, shifting sediment in the North Sea has caused problems with submarine cables, where shifting sand waves up to 10 m high are constantly changing (Drew and Hopper 1997). Cable, once buried, has become exposed and suspended between sand mounds. In an analysis conducted for the International Cable Protection Committee, Drew and Hopper (1997) concluded “In areas of shifting sediment where bottom fishing is practiced, there is great risk of cable damage.”

5.3 Feasibility of Cable Burial on the Existing PC-1 Routes in OCNMS

As noted above, plowing operations during the original installation were unsuccessful in achieving cable burial ≥ 0.6 m for at least one fifth of the PC-1 cable routes in OCNMS, or a minimum of 11.0 km (6.8 miles or 20.0%) of PC-1 East and 14.7 km (9.1 miles or 28.5%) of PC-1 North (Table 1). ROV jetting operations at PLIB sites, covering a cumulative distance of 4.6 km, were also unable to achieve cable burial to ≥ 0.6 m. Failure to achieve cable burial to target ≥ 0.6 m depth over sizeable portions of the PC-1 routes in OCNMS appears to conflict with the statement that “the proposed route has suitable substrate for cable burial along the entire route. The rocky substrate types consist of gravel and cobble that can be ploughed (in contrast to hard rock substrate, which cannot be ploughed)” (p. 17, SEA 1999). The feasibility of cable burial has implications for the analysis of remediation alternatives provided in this document. Review by NOAA’s experts indicates the substrate is suitable for plow burial with limited exceptions (see Section 5.3.1). .

5.3.1 Seafloor Geology

Two marine geology experts experienced with submarine cable route assessment independently consulted with NOAA and reviewed geophysical data from pre-installation surveys (C&C Technologies 1999), side-scan seafloor substrate characterization, installation operations reports (Tyco 2000a, Tyco 2000b), and post-installation video of the seafloor and cables. Both experts concluded that the sediments along the existing PC-1 routes in OCNMS are suitable for plow burial, with exception of limited areas (Bornhold 2003b, Greene and Watt 2002). Greene and Watt (2002) reviewed video clips selected to include locations where cable was unburied and suspended above the seafloor that covered 42% of the PC-1 East route and 9% of the PC-1 North route. Based on the appearance of the seafloor substrate, indications of plow performance (i.e., a

visible trench or not), and acoustic seafloor substrate characterization, they concluded seafloor conditions along most of the cable routes are favorable for cable burial. Greene and Watt did identify one area at the western end of the PC-1 East route where a concentration of boulders and angular slabby material, possibly carbonate-like rock or partially cemented clastic rock, was noted that might have prevented plow burial of cable to ≥ 0.6 m depth. This section of the PC-1 East route was estimated to be 982 m long, or approximately 2% of the total route length, and it might have been avoided with a minor route adjustment.

Bornhold (2003a and 2003b) completed a more thorough review of all available video from the June 2001 ROV survey and additional video collected by OCNMS in 2000 and 2001 from areas not covered by the June 2001 survey, as well as route survey reports, operations reports, and cable burial assessment reports prepared by contractors to PCL (C&C Technologies 1999, Tyco 2000a, Tyco 2000b, ERM 2001a, ERM 2001b, ERM 2002). Video coverage was available for 79.6% (43.7 km) of PC-1 East and 93.3% (48.0 km) of PC-1 North routes. Bornhold (2003b) described mildly deformed, stiff, overconsolidated pebbly marine and glaciomarine gray muds that underlie surface sediments of varying thickness over most of the routes. One factor that influences the operation of a cable plow is sediment shear or soil strength, basically a measure of a soil's stiffness or resistance to shear based largely on frictional and cohesive properties. A single sediment core sample from the geotechnical survey contained this sediment type in OCNMS, and it produced a shear strength value of 81 kPa (C&C Technologies 1999). The shear strength of soft sand or mud is about 5 kPa and hard clay is 50 kPa. All other sediment samples collected for the geotechnical survey had shear strength values < 20 kPa ($n=4$; C&C Technologies 1999). The RCBAR noted that the effective operational limits are about 100 kPa for plows and 50 kPa for ROV jetting (ERM 2002). Thus, if the sediment core is representative of other areas of overconsolidated mud, the plow should have been capable of cutting into this sediment to form a trench. In fact, videos of the cable routes confirm that the plow was capable of penetrating into the seafloor to create a trench in most environments and in a wide variety of seafloor materials encountered, including the overconsolidated pebbly mud (Bornhold 2003b). In many places, this mud is exposed in near-vertical walls of a trench that has partially filled with backfill material. In many places, the cable was visible, unburied on or suspended above the sediment surface where the plow clearly had penetrated well into the sediment (Bornhold 2003b). In other areas, steep slopes and undulating sediment topography, such as sand waves, contributed to unburied and suspended sections of the PC-1 cables in OCNMS (Bornhold 2003b). Bornhold concluded that many areas of cable exposure or suspension clearly were not attributable to seabed condition, rather it was operational factors, such as cable tension, that contributed to failure to achieve cable burial (Bornhold 2003b). A quantitative analysis of route distance where the plow should have been capable of cutting a trench was not conducted because the nature of subsurface sediments was not well characterized in pre-installation surveys and not consistently indicated in underwater videos. The evidence is clear, nevertheless, that substantial portions of the route where cable burial was not achieved have sediments conducive to plow burial under appropriate operational conditions. NOAA has concluded that deficiencies in both pre-lay survey data and route selection using the available data, as well as operational factors and decisions made during cable installation, compromised effective plow burial through the sanctuary.

5.4 Relation of Cable Condition to Current Fishing Activities

As noted in Section 4.4.2, groundfish trawl and longline fisheries have potential to interact with unburied and shallowly buried PC-1 cables in the sanctuary. This is a concern because fishing gear can damage the LWA cable and necessitate cable repair operations that will disturb large areas of seafloor in the sanctuary (see Section 5.6). Also, the present cable conditions detrimentally interfere with fisheries by presenting a safety risk, leading fishers to avoid areas of exposed cable and concentrate fishing effort in other areas. The most recent non-tribal trawl data available (1999-2001) reveals that hundreds of bottom trawl tows occurred annually near the PC-1 cables. Because shallowly buried cable is widely distributed over the PC-1 routes in the sanctuary and the precise route for the bottom trawls is not reported, all trawls near the cables could potentially impact shallowly buried PC-1 cables. The greatest risk of damage to fiber optic cables and safety to fishing vessels, however, is associated with unburied and suspended cable. Because unburied and suspended cable is widely distributed over the PC-1 routes in OCNMS (Figure 1), nearly all bottom trawling that occurs near the cables has potential to hit and snag PC-1 cables, threatening vessel and crew safety and potentially damaging the cables and fishing gear.

Two fishery management changes since 2003 could alter the potential for interaction between non-tribal bottom trawlers and unburied PC-1 cables, the rockfish conservation area and the vessel buyout program. In 2003, a rockfish conservation area was established off Washington, Oregon, and California where non-tribal groundfish bottom trawling was closed between specified depth contours. In 2003, this was between 183 m (100 fathoms, 600 feet) and 457 m (250 fathoms, 1500 ft) (Figure 9). In 2004, the closed area changed seasonally and was between 137m (450 feet) and 366 m (1,200 feet) in January-February, 110 m (360 feet) and 366 m (1,200 feet) in March-April, 110 m (360 feet) and 274 m (450 feet) in May-June, and 137m (450 feet) and 274 m (450 feet) in July-December. In 2005, the rockfish conservation area was between 137m (450 feet) and 366m (1,200 feet) between November and February, and 183m (600 feet) and 366m (1,200 feet) for the remainder of the year. These area closures leave nearly the entire PC-1 cable route open to bottom trawling but close much of the area to the fixed gear fisheries. The rockfish conservation area represents approximately 20% of groundfish trawling effort in the vicinity of the PC-1 cables. The effect of these area closures could be to displace effort to other preferred trawling areas, including areas in the vicinity of PC-1 cables.

A federally sponsored vessel buyout program in 2003 reduced the non-tribal trawler fleet operating off Washington approximately 50% to about 7 active vessels. The exact size of the fleet that will be actively working the sanctuary area is uncertain. Trawling permits allow any of the 181 vessels with current trawl permits for the California-Oregon-Washington coast to fish off Washington and within OCNMS. Because rockfish conservation areas implemented off California are more restrictive than those off Washington and Oregon, it is possible that some trawlers will shift their operations to take advantage of better opportunity off Washington. As a result, the level of trawling effort that will occur near the PC-1 cables in the future cannot be predicted.

The evaluation of risk to fishers and to cable integrity provided in this document is limited because it does not incorporate detailed information about the Makah trawl fleet, and it represents a relatively short time period in the recent past. The Makah tribal groundfish fleet has expanded in recent years as the non-tribal fleet has decreased. Moreover, tribal fishers are not currently

subject to the same depth and area based restrictions that are imposed on non-tribal vessels and theoretically could trawl anywhere along the PC-1 routes in the sanctuary (see Section 4.4.2). It is certain that tribal fishers currently exercise their treaty guaranteed right to fish within their U&A area and that fish resources exist in areas where PC-1 cables are exposed and poorly protected from external aggression.

A geospatial analysis of non-tribal commercial trawl effort in OCNMS between 1989 and 1996 showed that trawl effort shifted over time, based on changes in regulations, vessels involved in the fishery, species targeted, and groundfish abundance in different areas (Shoji 1999). Although there is a recent trend towards increased restrictions on the non-tribal groundfish fleet on the entire west coast of the U.S., one cannot assume that this fishery will be halted in the immediate future, nor that areas fished in recent years are representative of areas that will be targeted for the next 20 years or so. It is clear that this fishery will change over time in both the areas targeted and the number of vessels and individual trawl sets made. As a result, one cannot assume that the risk to PC-1 cables and trawling vessels and crews will diminish in the near future.

Physical encounters with the PC-1 cables have been reported by fishers working in the vicinity of the cables. An incident report of suspected fishing gear entanglement with PC-1 cables is provided in Appendix B of the revised burial assessment report (ERM 2002). In May 2002, a bottom trawler, the F/V Sea Otter, reported to the fishing liaison service for the PC-1 cable that his gear was entangled on the cables. However, the gear was freed from the snag without outside assistance or significant loss of gear. Although the fisher liaison concluded the fisher was not snagged on PC-1 cables based on coordinates for the cables and vessel position, the skipper, who has fished the area for many years, remains confident that his gear was temporarily entangled with a PC-1 cable (Alan Hightower, personal communication).

Makah Tribal fishers also have reported loss of longline gear due to snags on the PC-1 cables (Tyler 2003). Monitoring surveys conducted by NOAA in 2000 and 2001 covering approximately 23% of the cable routes revealed 15 incidents of fishing gear, such as snarls of line, lures, and large fishhooks, snagged on the PC-1 cables. This gear reconfirms the potential for fishing gear to contact and damage the cables, as well as the potential for gear to accumulate on the cables and impact sanctuary natural resources through ghost fishing (see Section 6.1).

A cable failure and repair operation on the PC-1 cables in Canadian waters is suspected to have been caused by trawler hits (see Section 5.6).

5.5 Vessel Safety

Suspended cables offer a real threat of gear entanglement and loss of fishing gear, as well as cable damage. When trawl gear traversing the seabed encounters a suspended cable, the trawl doors, bridles and/or the footrope of the net can pass under the suspension to become snagged. Entangled gear is a considerable safety threat to the vessel and its crew. The vessel is essentially tethered to the seafloor with the towline attached to the vessel's stern, generally the portion of the trawler with the least freeboard or lowest height above waterline (Figure 6). This makes the vessel vulnerable to swells, waves, and rough seas that are the norm for the area. A typical Notice to Mariners (NTM) for a submarine cable advises a vessel owner who suspects entanglement on a cable to contact a liaison (typically an international service) who advises the

captain of a course of action. If the vessel's position is over a submarine cable, this likely means cutting the towline and abandoning the gear to prevent damage to the cable. During this period of consultations, a vessel has very limited ability to maintain safe steerage, particularly if the seas are rough.

5.6 Risk of Cable Fault Requiring Repair

Several aspects of the PC-1 cables in their current condition increase the probability of cable fault: 1) multiple suspensions exist over boulders and other hard substrate that can cause accelerated physical wear by chafing leading to external and internal damage to cables and premature failure, as is already evident with outer serving damage at several locations; 2) the cables have high residual or permanent tension applied, which increases the risk of cable damage from external aggressions; 3) the light wire armor cable used is not designed to be laid unburied in areas of active bottom-contact fisheries; and 4) shallowly buried, unburied, and suspended cable sections are susceptible to damage from fishing gear used by bottom trawling and long line fleets that actively fish along the PC-1 routes through OCNMS.

Submarine cables, particularly LWA cables, are most susceptible to damage when they can be hit and abraded, where they are suspended above the seafloor and lying over hard substrate, such as boulders. Burial of submarine cables to 0.6 m or more is an industry standard for protection of cables from external aggressions in continental shelf areas (Drew and Hopper 1997), and development of the cable installation seafloor plow technology in the 1970's was a direct response to this need (Allan and Comrie 2001). Failure to successfully bury and protect the PC-1 cables over major portions of the routes in OCNMS increases the risk or likelihood that cable faults will occur and require repair.

The Submarine Cable Improvement Group (SCIG) is a consortium of four companies, Alcatel Submarine Networks, Global Marine Systems Ltd., KDD Submarine Cable Systems and Tyco Submarine Systems Ltd. that represent the vast majority of the supply industry for transoceanic cable systems. According to their mission statement, SCIG was formed "to improve submarine cable reliability through more efficient and cost-effective methods for cable burial and subsequent protection" (SCIG 2003). SCIG describes LWA cable as suitable for ocean burial, where additional in-situ protection is necessary. LWA cable was not designed to withstand persistent suspension and external aggression. The LWA cable used for the PC-1 network in coastal shelf areas has an outer diameter of 29 mm (1.1 inch) and is composed of 2 thin layers of tar-soaked yarn (the serving), a layer of galvanized wire (3.35 mm diameter thickness), a layer of polyethylene insulation (4 mm thick), a solid copper sheathing, and 2 layers of steel wires (about 4 mm total thickness) surrounding the optical fibers held in a thin plastic layer (Figure 13). Typically, more heavily armored cable such as single armor medium, single armor heavy, or double armor cable is installed in areas where it is anticipated that a cable will be unburied or subject to suspensions, there is a high risk of trawler damage, or natural and other anthropogenic threats (SCIG 2003). These heavier cables have a thicker wire or additional layers of protective wire that armor the optical fibers held at the core.

A cable engineering expert who reviewed installation data and video of the PC-1 cables in OCNMS characterized the probability of one or more faults as very high (Wilson and June 2002). This assessment has been supported by required repairs to the PC-1 cable in Canadian waters just

west of the OCNMS boundary. The following sections provide a more thorough discussion of the risks of cable failure associated with unburied and suspended sections of the LWA cables on the PC-1 system in OCNMS.

5.6.1 Cable Failure Due to High Residual Tension and Chafing

Any cable in suspension is in a far harsher environment than if it were lying on an unconsolidated sedimentary seabed (i.e., mud, sand, or gravel) or buried ≥ 0.6 m under the seabed (Wilson and June 2002). When a cable is suspended, two factors are evident: 1) the cable is under tension, or else it would settle to the seafloor; and 2) all the weight of the cable in suspension is borne by the two contact points. Damage to the cable can result at these contact points due to high residual tension on and sharp bends in the optical fibers, as well as direct, persistent physical abrasion of the cable.

In the case of the PC-1 cables in OCNMS, higher than normal tensions are permanently applied to the cables, as indicated by residual tension values recorded during installation and currently evidenced by multiple cable suspensions (Wilson and Darbyshire 2003).

Vibratory movements of a suspended cable, or strumming, can cause physical abrasion and gradual wear on the outer protective serving layer, armor wires and polyethylene insulation at points where the cable contacts the seabed or a boulder (Figure 12). The cable is most likely to be damaged by strumming and physical abrasion where it remains in constant contact with hard substrate. Excessive wear on a submarine cable will eventually cause a shunt fault and possibly a full fiber break fault.

Video interpretation provided in the RCBAR noted 9 cable suspensions on PC-1 North, the highest of which were 0.6 to 1.0 m above the seafloor (ERM 2001a, ERM 2002). On PC-1 East, 98 suspensions were noted in video logs (Appendix J, ERM 2002). Long suspensions add a considerable weight of unsupported cable and lead to increased tension and wear at the nodes of suspension. PC-1 East has 19 cable suspensions over 30 m long and six suspensions 0.5 to 0.6 m above the seafloor (Appendix J, ERM 2002). A review of video logs from the June 2001 survey and surveys conducted by OCNMS identified 5 places on PC-1 North, and 19 places on PC-1 East where the cables are lying atop or deflected by boulders (Figure 12) and serving (outer protective layer) damage and exposed armor at 18 places on PC-1 East. A polished appearance to the metal armoring and lack of biofouling indicates that physical abrasion is actively occurring at some of these locations.

5.6.2 Natural and Anthropogenic Threats to Submarine Cables

Unburied and suspended submarine fiber optic cables on the continental shelf are also susceptible to damage resulting from natural events and human-caused activities. Natural threats include damage from animals such as marine mammals, fish, sharks and invertebrates, or damage due to landslides or seismic events. Modern submarine cables are armored and constructed with several protective layers that eliminate nearly all risk of cable damage from aquatic biota, such as shark or fish bites. Earth movements have been responsible for a low percentage of cable faults in recent years (Featherstone et al. 2001), a risk that was addressed in the Final Route Survey Report for the PC-1 cable system (C&C Technologies 1999). There are, nevertheless, a variety of

potential human-caused threats to unburied cables on the continental shelf, including fishing gear and anchors.

Of particular concern for the PC-1 cables in OCNMS is commercial bottom trawling. Bottom trawling is an active fishery in areas where known exposures, suspensions, and shallow burial of PC-1 cables exist (see Section 4.6). The otter doors and the ground gear on the footrope of the net can snag, entangle, pinch, crush or slice the protective coatings on the submarine fiber optic cable, as well as damage the internal fiber bundle by physical impact. In fact, fishing causes more than 65% of submarine cable faults, and bottom trawls caused the majority of the faults (Drew and Hopper 1997). Trawlers operating in OCNMS use steel doors that weigh up to 2,000 pounds each (NRC 1994). A trawl door striking a fiber optic cable can easily cause a fault by generating excess tension or bending a cable beyond acceptable limits, without actually parting the cable (Drew and Hopper 1997). The typical trawler operating in the vicinity of the PC-1 cables uses a ¾ inch steel tow cable with a breaking load of about 30 short tons. For comparison, the NTTS of LWA cable is 22.4 short tons. Therefore, trawler tow cables are nominally “stronger” than LWA fiber optic cables. There is a high probability that a fiber optic cable about an inch thick can be damaged by a narrow steel object, such as a trawler door, weighing hundreds of pounds, traveling at 2-4 knots, being pulled by a vessel with a mass of tens or hundreds of tons. In addition, the impact and pull exerted by the front or bottom edge of trawler door is a very localized force that could exceed the minimum bending radius specification of LWA cable and cause damage even before cable tension exceeded design standards.

Cable burial to ≥ 0.6 m is an industry standard dating from the 1980’s to protect submarine cables from external aggression and provide a low risk of cable fault. In fact, the typical specification for burial depth has increased in recent years from 0.6 m to 1.0 m or more (Mole et al. 1997, Allan 1998, Allan and Comrie 2001). This specification is based on a number of variables, such as sediment type, gear penetration, a safety factor, sediment mobility, and inaccuracy of cable burial depth measurement. The protection provided to a cable by overlying sediment varies with sediment characteristics such as firmness, stiffness, or shear strength. A firm or hard sediment type with high shear strength (e.g., fine sand or rock) resists penetration by anchors and trawl equipment better than softer sediment (e.g., mud, silt, or coarse sand). Burial protection index (BPI) is a concept that acknowledges that the degree of cable protection varies with the nature of the substrate (Mole et al. 1997, Allan 1998). Although BPI has value for site-specific assessment of cable protection, a fixed burial depth is typically applied to a cable burial project through an area with variable sediment characteristics. The widely accepted estimate for maximum penetration of trawl gear is 30 cm (0.3 m) (see Section 4.4.2), which is typically increased by a safety factor of 33% to 100% (Allan 1998, Hoshina and Featherstone 2001). NOAA maintains that the Permit condition for burial to 0.6m reflects a reasonable measure of “low risk”.

Where seafloor sediments are mobile, the thickness of overlying sediment and protection provided to a fiber optic cable can vary over time (Allan 2000). Areas of mobile seafloor sediments, as indicated by the presence of sand waves, have been found at several locations along the PC-1 routes in OCNMS and are located where shallowly buried and unburied cable was found in 2001 (Figure 3). The presence of mobile sediments can influence analysis of cable burial depth and risk of external aggression in several ways, but fundamentally mobile sediments indicate an area where deeper burial is preferable to shallow burial for cable protection. For example, SCIG’s information guide notes that where the fishing threat is high, “burial would be

deemed necessary in average seafloor materials. If the seabed material is known to be seasonally mobile, greater burial may be required” (SCIG 2003).

Suspended sections of the PC-1 cables are under constant tension and, due to their position above the seabed, are most vulnerable to damage from fishing gear. There is a minimum cumulative distance of about 1.4 km of suspended cable along the PC-1 routes within OCNMS. Some of these suspensions are sufficiently high off the seabed (e.g., >0.5 m) to present an entanglement threat for trawl doors and nets that could snag under the cable during normal fishing operations. In addition to potential for damage to the cables and fishing gear loss, unburied and suspended cables present a threat to the safety of fishing vessels and human life (see Section 5.5).

Trawling gear is not the only fishing equipment that poses a threat to PC-1 cables. Where cables are unburied, longline fish hooks can snag and penetrate the polyethylene insulate sheathing of the LWA cable to cause high voltage blowouts and shunt faults and can also damage the glass fibers (Drew and Hopper 1997). In the longline fishery, the force generated in trying to clear a snagged longline can be enormous, estimated at up to 4 tons (Drew and Hopper 1997). Moreover, longlines used off Washington typically terminate with anchors, called mud hooks, which can snag an unburied or shallowly buried cable. Monitoring surveys conducted by OCNMS in 2000 and 2001 covering just 23% of the cable routes revealed 15 incidents of small fishing gear, line, lures, and exposed hooks on the PC-1 cables.

6.0 ENVIRONMENTAL CONSEQUENCES OF PC-1 CABLES IN THEIR CURRENT STATUS

This section describes the current ongoing and potential environmental consequences of the PC-1 cables in their current condition, with extensive areas of shallowly buried, unburied, and suspended cable within OCNMS (also discussed in Sections 5.4, 5.5, and 8.1). Although the SEA described effects of cable installation on benthic communities as a one-time, short-term and highly localized disturbance associated with route clearing, installation plowing, and post lay burial operations, with a very low risk of cable failure and probability of future seafloor disturbance (SEA 1999), shallowly buried, unburied, and suspended cables can result in both continual ongoing environmental impacts and elevated risk of considerable and multiple disturbances to the sanctuary seafloor throughout the service life of the cable. The disturbance and risk to the habitat and benthic communities resulting from the current cable conditions cannot be quantified in terms of probability or economic value because of intangibles, such as timing, number and locations of probable faults, inevitable changes in commercial fishery usage, as well as the lack of established methodologies for economic valuation of deep-water seafloor biological resources. The main environmental consequences of inadequately buried PC-1 cables in OCNMS are ghost fishing, marine mammal and seabird entanglement, ongoing seabed disturbance, and potential future disturbance from repair activity, as discussed below.

6.1 Ghost Fishing

Ghost fishing refers to catch of mobile marine life in fishing gear that has been abandoned in the sea, or derelict fishing gear. Unburied and suspended cables provide a physical feature on which fishing gear can snag and become unrecoverable, causing it to be abandoned. Derelict gear also can be generated by abandonment of gear caught on natural bottom features in the vicinity of

submarine cables, where common retrieval techniques are discouraged due to proximity to cables. Typically, trawlers and longline fishers use grapnel hooks to drag the bottom in an effort to retrieve gear lost or snagged on the bottom (Drew and Hopper 1997). Near a submarine cable, there is a risk that the grapnel hook will snag and potentially damage the cable. Thus, cable companies request that fishers avoid use of grapnel hooks near submarine cables, and they typically provide compensation for gear lost near a fiber optic cable even if it is suspected that natural features cause the snag (Scott McMullen, OFCC, personal communications). Because cable companies are concerned that attempted recovery of snagged fishing gear can further damage cables, it is common practice for cable companies to request and recommend that fishers who suspect entanglement with submarine cables cut their tow lines and abandon their gear. The draft NTM for the PC-1 project includes a request that fishers with gear snagged near PC-1 cables do not try to retrieve gear, and it provides a 24-hour emergency contact number for an on-duty manager to liaison with fishers (Appendix C, ERM 2002). Consequently, burial of fiber optic cables in areas with active bottom contact fisheries is critical, not only for maintenance of cable integrity but also for protection of natural resources because removal of derelict gear is not feasible from deep waters.

Fish caught in derelict gear also provide an attraction for seals and sea lions that are common in OCNMS, feed on fish, and are capable of diving to depths where the PC-1 cables lie where they are at risk of entanglement (see Section 6.2).

Retrieval of entangled nets and other gear from depths beyond the range of SCUBA and without the use of grapnel hooks is not commonly attempted (Jeff June, NRC, Inc. personal communication; Dan Chia, California Coastal Commission, personal communication). Derelict gear retrieval from near the PC-1 cables in OCNMS, at depths of between 100 and 300 m, would require use of an ROV or manned submersible. However, operators of such deep diving equipment strictly avoid work with materials and in areas where there is a risk of entanglement that could cause damage or loss to their equipment and personnel (Chris Ijames, Delta Oceanographics, personal communication). As a result, there is no reliable method for removal of gear caught on unburied submarine cables at depths beyond the range of SCUBA (i.e., ≥ 50 -70 m). The risk of gear entanglement and lack of technology to safely retrieve derelict gear are additional reasons why submarine cable burial is an industry standard for continental shelf areas where commercial fishing occurs. Within OCNMS where the PC-1 cables are laid in waters over 100 m deep, approximately 2.4 km of PC-1 cables are unburied and 1.4 km are suspended up to 1 m above the seafloor, where they are at risk of snagging fishing gear and creating an entanglement hazard.

6.2 Marine Mammal and Seabird Entanglement

Marine mammals and seabirds can become entangled in the PC-1 cables and derelict gear, particularly where the cables are suspended above the bottom. The risk of marine mammal and seabird entanglement in PC-1 cables in OCNMS is reduced, however, by the position of suspended cables relatively close to the seafloor.

6.2.1 Deep Diving, Air Breathing Species in OCNMS

Several species of marine mammals are known to be deep divers, as evidenced by long dive times, direct evidence (i.e., tracking devices), and stomach contents. Beaked whales (e.g., Baird's beaked whale *Berardius bairdii*), sperm whale *Physeter macrocephalus*, pygmy sperm whale *Kogia breviceps*, and northern elephant seal *Mirounga angustirostris* are examples of deep diving species that are occasionally found in OCNMS waters. Gray whales *Eschrichtius robustus* are one common cetacean in OCNMS that regularly forage along the seafloor. Their habit of plowing sediment for invertebrates makes them particularly susceptible to encounters with unburied and suspended submarine cables. Although gray whales are capable of foraging at depths greater than 100 m, the risk of entanglement is reduced because they typically forage in shallower areas (Cacchione et al. 1987). Several species of seals and sea lions commonly found in OCNMS waters, harbor seals *Phoca vitulina*, northern sea lions *Eumetopias jubatus*, and California sea lions *Zalophus californianus*, also have been documented to forage at depths where they might encounter PC-1 cables (i.e., >100 m) (Stewart and DeLong 1994, Small et al. 2001). In addition, some species of seabirds are capable of diving to depths in excess of 100 m. For example, common murre *Uria aalge* are known to regularly dive to 70 m depth, with occasional dives as deep as 180 m (Piatt and Nettleship 1985, Bryant and Jones 1999). It is possible that any of these species capable of diving beyond 100 m depth can become entangled on the PC-1 cables or derelict gear.

Sperm whales are the deepest and longest diving of all cetaceans, and the only cetacean species confirmed to have been entangled in a submarine cable in 1955 (see Section 6.2.3). Although sperm whales do forage at depths where the PC-1 cables lie in OCNMS, sperm whales are not known to be abundant in OCNMS. Marine mammal surveys indicate that sperm whales are found off Washington State from spring to fall and are typically beyond the continental shelf, along the slope (200-2,000 m) and in deeper offshore waters (>2,000 m) (Brueggeman 1992). A review of all sperm whale sightings recorded by NOAA during recent aerial and ship surveys off California, Oregon, and Washington waters indicated that the nearest sighting off Washington state was approximately 60 nmi (69 miles) from shore, west of the OCNMS boundary (Jay Barlow, NOAA SW Fisheries Science Center, personal communication).

Although there is potential for deep diving marine mammals and seabirds to become entangled on the PC-1 cables, the condition of the cables reduces the probability of marine mammal and seabird entanglement. Most suspensions of the PC-1 cables in the OCNMS are generally between 0.1-0.25 m (4-10 inches) off the seafloor, but six suspensions between 0.5 and 0.6 m (20-24 inches) were noted on PC-1 East and two suspensions up to 1.0 m high (40 inches) were noted on PC-1 North (Appendix J, ERM 2002). Because these suspensions lie close to the seafloor, a marine mammal or seabird would have to be foraging directly at the seafloor surface to become entangled with a cable. Furthermore, the cables are under tension (i.e., taut), and no standing loops have been found, which reduces the likelihood of animal entanglement. However, the risk of entanglement is remote.

6.2.2 Endangered Species Act Listed Diving Species in OCNMS

Entanglement in unburied cable could result in “take” (i.e., injury or mortality) of an Endangered Species Act (ESA) listed species. ESA listed species found in OCNMS that commonly dive to depths for feeding are the humpback whale *Megaptera novaeangliae*, blue whale *Balaenoptera musculus*, fin whale *Balaenoptera physalus*, sei whale *Balaenoptera boreali*, sperm whale, leatherback sea turtle *Dermochelys coriacea*, green sea turtle *Chelonia mydas*, loggerhead sea turtle *Caretta caretta*, and olive ridley sea turtle *Lepidochelys olivacea*. In addition, marbled murrelets *Brachyramphus marmoratus*, brown pelicans *Pelecanus occidentalis*, and short-tailed albatross *Phoebastria albatrus* are ESA listed birds that forage in surface waters. Of these species, only sperm whales have opportunity to encounter unburied and suspended portions of the PC-1 cables in OCNMS because of their deep water feeding habits, but their presence in the sanctuary has not been documented. All other ESA listed species are baleen whales or surface oriented foragers that typically feed in the water column.

6.2.3 Documented Entanglement

Heezen (1957) documented marine mammal entanglement in submarine cables based on data from the late 1800s to 1955. All identified specimens were sperm whales. The author concluded that the sperm whales became entangled in extremely slack or looped cables while foraging along the seafloor. No instance of marine mammal entanglement in submarine cables has been documented since the 1950s (STARS 2002). Advances in electronic navigation and vessel positioning, more accurate control of cable payout, and improved route selection and burial technologies have reduced the threat of entanglement by minimizing looping in cables (STARS 2002).

6.3 Ongoing Seabed Habitat Disturbance from Cable Movement

Unburied and suspended cable can prevent recovery of the seafloor and its community to their natural state by causing persistent disturbance to a localized area from strumming, from the cable being snagged and pulled along the bottom, and by changing the physical and biochemical nature of the substrate. Strumming, or the vibratory movement or oscillation of cable, occurs when unburied and suspended cable is exposed to water current of sufficient velocity. Physical disturbance to substrate and the associated biological community will occur at points where the cable contacts the seafloor or where vibrations are sufficient to generate localized water movements that displace sediment materials. The direct result of cable strumming is to maintain a localized area of persistent disturbance that prohibits establishment of a normal community of benthic organisms on the surface of sediment or hard substrate.

Disturbance to seafloor habitat from the movement of unburied and suspended cable sections has not been well studied at sites of other submarine cables. Clearly, few infaunal organisms will survive along a persistently disturbed track under a section of strumming cable. Such disturbance was noted along the PC-1 cable routes during OCNMS submersible surveys that provided a few hours of observation time and cover a small portion of the PC-1 routes in OCNMS. One can assume that strumming will occur on a periodic basis, associated with daily tidal currents and seasonal storm events. The area disturbed from strumming can be roughly estimated from OCNMS video to be the upper few centimeters of seafloor over an area of ≤ 10 times the width of

the cable. In the case of the PC-1 cables in OCNMS, the width of disturbed area is relatively small because the cables are generally under tension, which prohibits them from moving widely over the seafloor.

Seafloor impacts of strumming and movement of unburied cable are not restricted to soft substrates that dominate the PC-1 routes in OCNMS. The ability of unburied cable to impact harder consolidated seafloor materials was revealed during recent monitoring of the Acoustic Thermometry of Ocean Climate (ATOC) cable, a surface-laid submarine cable near Santa Cruz, California. Researchers noted several areas where cable had worn grooves into soft bedrock and kept the rock surface devoid of organisms at points of contact (Irina Kogan, Monterey Bay National Marine Sanctuary, personal communication). Furthermore, in some locations the cable had shifted position and created several adjacent areas of eroded substrate. Although the circumstances differ for the ATOC and PC-1 cables, monitoring of the ATOC cable demonstrated the types of impacts an unburied cable can have on physical habitat and local biological community.

Seafloor disturbance resulting from unburied cable also can occur if a cable is snagged, pulled from the sediment, and dragged across the seafloor when entangled by trawl gear. Snagged trawl gear can potentially pull the cable several meters along the seabed and, in the process, can expose further length of cable. The sweeping motion of the cable being pulled from or across the sediment, plus the trawl doors lying on their sides during the attempt to retrieve the gear, will disrupt the seabed and damage or kill epifauna and infauna. Longline and pot gear are unlikely to displace the cable very far due to the lower breaking strength of the longline hooks and mainline to the surface float(s).

Although disturbance that results from cable strumming is likely to have a localized impact on biological community and seafloor sediments, these impacts are representative of the subtle effects of seafloor disturbance that OCNMS regulations seek to prevent. Although there are several exceptions (including traditional fishing operations), OCNMS regulations prohibit altering the seabed of the sanctuary (15 CFR 922.152(a)(4)). Moreover, special condition 2.B.i of the Permit requires that “the ongoing placement and operations shall be conducted in a way that does not destroy, cause loss of, or injure Sanctuary resources.”

6.4 Impacts of Cable Repair and Reinstallation

Although the PC-1 cables in their current condition cause ongoing impacts to the seabed and associated natural resources within the sanctuary, perhaps the most extensive impacts are associated with potential future repairs that could be required due to failure of service or cable fault. NOAA has strong concerns that large-scale seafloor disturbance may occur repeatedly, over an extended period of time as repeated repair operations are required to maintain cable integrity. These concerns are reinforced by a repair operation on the PC-1 cables in Canadian waters, just west of the sanctuary (see Section 5.6).

The SEA provides a general description for the process of a cable fault repair (pp. 8-9, SEA 1999). Once the fault location has been ascertained as accurately as possible, the preferred method for recovery of a buried cable in waters shallower than 2000 m is to use an ROV to accurately localize the fault using electrical ‘toning’ techniques. Once the fault has been located,

the ROV will uncover and then cut the cable at a point as close as possible to the suspected fault point. The ROV will then attach lift lines that the repair vessel will use to recover the cut cable ends. Assuming that the reported fault has been accurately located, cable retrieval by this method limits the distance of cable pulled from the seabed to approximately twice the water depth at the fault location.

The alternative to the ROV for cable retrieval is a large detrenching/cutting grapnel that is dragged across the seafloor perpendicular to the as-laid cable line to intersect and cut the cable. Typical grapnels for retrieval of buried cable are huge metal tools over 3 m (10 feet) high that plow a swath over 1 m deep into the sediment. Assuming grapnel tows are well placed relative to the cable, at least three passes with the grapnel are required – one to cut the cable, a second to bring up and buoy one end of the cable, and a third to bring up the second end. Because locating a cable fault from shore terminal stations can be an imprecise operation due to the distances involved, it may be necessary to extract substantial cable length from the sediment in order to bring the precise fault point onboard the repair vessel, which expands the area of seafloor disturbance. Should the initial cutting or holding grapnel drives be unsuccessful, due perhaps to the cable location being different from its as-laid and charted position as a result of forces exerted by external aggression, then the seafloor will be extensively disturbed by repeated grapnel runs, cable being pulled from the sediment, and cable dragged across the seafloor as it is pulled by the grapnels (Wilson and June 2002).

Where the existing cables are buried, the sediment, infauna, and epifauna would be disrupted as the cables are lifted. If the cable retrieval vessel is not precisely over the cable route, some lateral movement of the cable along the seabed (e.g., several meters) would occur prior to its lifting off the seabed, which would disrupt the seabed to a depth of a few centimeters. Where a cable crosses hard bottom habitats, some damage to encrusted and attached biota can be expected as the cables are lifted off the seabed. Organisms could also be damaged when rocks are rolled or moved during the remediation operations.

After retrieval of the cable ends, the fault in the cable is cleared or cut out and a section of new cable is spliced in between the two cut ends to have them meet at the surface and restore connectivity. Then the cable is lowered to the seafloor in a U-shaped loop, known as a ‘bight’, perpendicular to the main cable route, followed by re-burial of the cable by jetting. The length of the additional section of cable is typically 2.5 times the depth of water (TyCom 2000). In sum, the length of disturbed seafloor from lifted and spliced cable add up to 4.5 times the water depth at the site, and more if grapnels are used. The disturbance extends up to a meter depth into the seafloor over an area about 1.0 to 2.0 m wide. The repair vessel crew normally will make every effort to minimize the length of extra cable required to complete the repair in order to preserve system transmission characteristics.

If a considerable length of cable is being reinstalled by plow, seafloor disturbance from the plow is caused when the plowshare and skids come into contact with the substrate. A 3 m plow with 2 m plowshare displaces soft bottom sediments to a depth up to 2 m over a width of several meters along length of targeted areas. The plowshare pushes sediments to either side and creates berms on each side of the trench. NOAA monitoring has revealed that berms are composed typically of larger particle sediment and blocks of consolidated sediments due in large part to the winnowing away of the finer unconsolidated materials. The trench bottom, locally protected from currents,

generally contains finer particle size materials than those in the berm. The degree of disturbance to the seafloor substrate is dependent on the type of substrate and on the ambient oceanographic processes. For instance, the trench and berms are still visible in many locations five years after the cables have been laid, particularly in areas of coarser substrates or consolidated sediments. In areas of unconsolidated silt or sand, the disturbance from the plow was observed six months after the plowing but was no longer discernable four years later.

The impact of plow skids on the seabed is one of broad shallow furrowing, crushing of epibenthic fauna and localized consolidation of some finer sediments. The disturbance is generally less significant than that caused by the plowshare.

It is unlikely that reinstalled cables could be laid precisely along the scar of the initial cable installation route, and adjacent unaffected habitat probably would be impacted by the burial operations. The deployment of splice boxes and cable bights would result in additional impacts of the seabed and natural resources, perpendicular to the original cable routes at each of the six final splice locations. At cable crossings and bight areas, a jetting ROV would liquefy the bottom sediments under the cable, resulting in displacement of sediments and injury or mortality of sessile organisms to a depth of approximately 0.5 to 1.0 m.

Cable repair operations impact both the physical and biological components of the seafloor. Jetting operations can disrupt the sediment stratigraphy (layering) by mixing sediment layers in a hydrolyzed blend, alter the physical composition of the substrate, and physically damage epifaunal (i.e., living on the surface) and infaunal (i.e., living in the sediment) organisms. Monitoring by NOAA has revealed that the physical effects of jetting can remain evident for years after the cables were laid, although these effects depend largely on the nature of the substrates prior to jetting. In areas that include primarily gravel or larger particles, jetting removed the finer components and left a coarser lag deposit of dominantly pebbles, cobbles and boulders because jetting suspends finer particles into the water column where they are carried away by seafloor currents. The process of jetting in coarse sediments thus alters the substrate considerably from undisturbed areas nearby. Attempts at jetting consolidated clays, while generally unsuccessful, have in some instances left a vertical wall of consolidated material, also changing the substrate from the undisturbed areas nearby. In contrast, a cable installation plow makes a deep cut into the seafloor into which the cable is placed. If equipped with a disc cutter, a plow can cut a wedge of sediment under which the cable is placed. Under ideal conditions, the sediment wedge falls back in place to leave a relatively minor path of disturbance with minimal disruption of sediment characteristics. While the disc cutter further reduces disturbance to sediment stratigraphy, a plow with or without a disc cutter is likely to be less disruptive of seafloor sediments than jetting operations that fluidize a swath of sediment and can cause loss of fine particles.

A description of the disturbance to benthic communities expected from plowing and jetting is presented in the SEA. Typically, most infauna lives in the surface layers of continental shelf sediment because inhospitable anoxic, or oxygen depleted, conditions occur within a few millimeters of the surface, except in localized areas where burrowing organisms oxygenate surrounding sediment. Repair operations can cause organisms to be physically damaged, dislocated from established “homes”, and smothered in anaerobic sediment. In addition, such physical disturbance can sharply reduce the structural diversity and habitat complexity of the

seafloor (NRC 2002). In many marine benthic systems, the structural complexity of benthic ecosystems is enhanced by growth and actions of living organisms such as foraminiferans, coralline algae, corals, sponges, brachiopods, bryozoans, worms, and mollusks. Even small scale biogenic features are important for small invertebrates and post-settlement fishes, providing surfaces for feeding and places to hide from predators. For example, juveniles of many fish species are known to associate with small-scale habitat features (e.g., Auster et al. 1994 and 1995). Structural diversity of seafloor habitat is critical for regulating population dynamics and species interaction of fish communities.

The physical disturbance to the seafloor caused by the cable installation and repair equipment, such as plows and water jetting tools, is commonly thought to be a short-term disturbance with recovery taking somewhere between several months to several years. Whereas physical recovery of the seafloor has been documented at other sites in terms of persistence of a plow trench, recovery of the biological community is relatively less well understood. Organisms adapted to frequent disturbance, as occurs in nearshore areas of the Washington coast, typically show behavioral adaptations to this regime such as tube building and penetration deep into the sediment (Jumars and Banse 1989). In contrast, organisms adapted to low levels of disturbance, as is typical for deeper continental shelf areas, tend to exhibit population level responses to disturbance (e.g., mortality). Epifaunal communities that stabilize sediments and those from areas with low rates of natural disturbance are particularly vulnerable to physical disturbance (NRC 2002). The most severe and persistent effects of physical disturbance to the seafloor are found where natural disturbance is the least prevalent, e.g. continental shelf, where storm-wave damage is negligible and biological processes tend to be slow (Watling and Norse 1998).

Monitoring of the PC-1 cable routes by OCNMS has shown that cable installation disturbance to benthic communities is still evident four years after the cables were laid. The communities currently present in the trench differ from those on the berm and in the undisturbed substrates nearby. This is not unexpected because the substrate composition on the berms and in the trench remains different from the undisturbed substrates nearby. In addition, where consolidated clays have been exposed on the berm or in the trench, re-establishment of benthic communities has been slower than on other substrate types. Benthic community structure appears to have re-established more rapidly in areas of finer, unconsolidated substrates than in areas of coarser or consolidated substrates. In areas where the cable is unburied but in contact with the substrate, including boulders, re-establishment of benthic communities can be delayed because movement (strumming) of the cable creates an unstable environment.

Potential types of impacts of cable repair activities extend beyond the seafloor and its communities to marine mammals and other diving marine wildlife. Marine wildlife can be harmed by entanglement with cables (see Section 6.2), entanglement with derelict gear (see Section 6.1), and collision with vessels.

6.5 Social and Economic Impacts

Shallowly buried, unburied and suspended cable is incompatible with bottom contact fisheries due to the risk of gear entanglement and loss, as well as the safety risk to vessels and crew (see Sections 5.4 and 5.5). Commercial fishers avoid portions of the cable routes where their gear could directly interact with these submarine cables, which results in a loss of area use to the fishers. Fishery management measures on groundfish harvest are leading to further area restrictions that could, in effect, concentrate fishing effort to smaller areas and potentially increase the trawling effort in the vicinity of the PC-1 cable routes (Section 5.4). Commercial fishers have expressed dissatisfaction with area loss and increased risks to vessel and crew safety to NOAA on several occasions. In addition, the Makah Tribal Council has written NOAA to express concerns about current and future impacts of the PC-1 cables on tribal fisheries (Tyler 2003). Specifically, Makah fishers consider that unburied cable poses a serious risk of entanglement for fishing gear and a safety risk to vessels and personal injury. Currently, Makah fishers try to avoid fishing in the vicinity of the cables, which are normally productive areas for fisheries, because of concerns about gear loss and vessel safety (Tyler 2003). Given the complex manner in which fishery regulations, seafloor habitats, fish stocks, and navigational hazards (e.g., submarine cables) all influence selection of the area fished, it is not possible to quantify the economic impacts to commercial fishers of the PC-1 in their current condition. Nevertheless, the loss of area use directly limits their ability to catch fish and could reduce the profitability of commercial fishing in the area. This loss will be increased if cable faults occur and repair operations are carried out further excluding fishing activities in the vicinity of the repair.

In addition, commercial fishers could suffer economic loss during repair activities because they would be excluded from the area(s) in which repair activities are underway, which typically last from one week to less than a month (Wilson and June 2002, CCC 2002).

7.0 ENVIRONMENTAL CONSEQUENCES AND RISKS OF REMEDIATION ALTERNATIVES

This section describes the eight remediation alternatives under consideration, and discusses the environmental and socio-economic impacts and risks and uncertainties associated with each alternative. As noted above, the alternatives are themselves mitigation measures. The description of the methodology of each alternative includes mitigation measures that would be implemented with each methodology. Prior to discussing each alternative it is necessary to define the different types of natural resource impacts or disturbance that can occur because it is not strictly the areal extent of disturbance that factored into NOAA's decision-making but also the nature of that impact or disturbance. Also, different remediation alternatives change to differing degrees the risks to and impacts on natural resources, fishers, treaty rights and cable integrity by increasing, decreasing or otherwise changing the nature of the risks.

For this analysis, long-term impact refers to one-time disturbances from which it takes several years for the seafloor habitat and benthic communities to recover. When the NOAA authorized cable installation through issuance of the Permit, NOAA accepted the long-term presence of the cable within OCNMS, but it did so with the understanding that installation was a one-time impact and the expectation that the seafloor and communities would recover over time with a low probability of limited disturbance from repairs. All of the alternatives, with the exception of No

Action, could involve further long-term disturbance to areas some of which were disturbed during the initial installation and have not yet recovered.

Short-term impacts are those that affect an area for several days to weeks. An example is a pile of sandy spoils resulting from manual clamming activity, which typically settle and redistribute to a natural contour within a few tidal cycles.

A one-time impact is contrasted with continuous, multiple or recurring impacts. A one-time impact was expected with cable installation, such that a plow and jetting ROV would disturb the seafloor and benthic communities a single time after which no additional impacts would occur unless repairs were necessary. One-time impacts are preferred to continuous, multiple or recurring impacts or to the risks arising from such impacts.

The terms multiple and recurring can be used interchangeably and refer to impacts or the risk of impacts occurring several times. Repair activities are an example of recurring disturbance because with each repair the seafloor is disturbed again. NOAA views multiple, recurring or repeated impacts or the risk thereof, as the least protective of the sanctuary resources, fishers and treaty rights. In addition, such impacts could involve disturbance to areas beyond the existing area disturbed from the initial installation. In the decision criteria these are termed future impacts.

Continuous, chronic, persistent or ongoing impacts are those that are ongoing, such as the potential for seafloor disturbance from strumming, ghost fishing and entanglement. Leaving the cable as is would result in continuous, ongoing impacts.

In addition to the temporal aspect of impacts, the nature and extent of physical disturbance are also of concern to NOAA. Cable route video and NOAA's monitoring studies have shown that seafloor impacts of the plow were distinctly less dramatic than jetting impacts. With the disc cutter in operation, the plow was designed to cut or lift up a wedge of sediment under which the cable was inserted. After the plowshare passed, the sediment could fall back into place. In consolidated sediments such as clay-mud, minimal disturbance to sediment stratigraphy or layering could result, and impacts to the benthic community would be reduced. With unconsolidated gravel, cobble, and/or sand sediments, the wedge of sediment could be more disturbed. More distinct disturbance, however, results from jetting of sediments to bury cable. The goal of jetting is to fluidize or liquefy sediments to allow the cable to sink below the surface. This process causes substantial disruption of sediment stratigraphy and can result in redistribution of finer sediment components, including net export of fine materials if water current is present to transport them away. Berms of coarse sediment materials lacking the fine materials are commonly visible from PLIB sites on the PC-1 cables. This causes substantial and immediate physical disturbance to seafloor organisms and can result in long-term alteration of sediment characteristics, which in turn affects the benthic community that will be restored in jetted areas.

7.1 No Action (Alternative 1)

Under the No Action Alternative, the PC-1 cables would remain in their current condition, with multiple sections of unburied and suspended cable in OCNMS. This alternative does not address

ongoing disturbance to sanctuary resources, infringement of Treaty fishing rights, risks to fishers, or the threat of multiple cable faults and future disturbance from repair activities.

7.1.1 Description of the Methodology (Alternative 1)

There is no methodology associated with the No Action alternative, and no cable engineering would be required.

7.1.2 Impacts to Natural Resources and Seafloor (Alternative 1)

The existing and ongoing environmental consequences and uncertainties of the No Action alternative are reviewed above in Sections 4, 5 and 6. Environmental consequences caused by PC-1 cables in their current condition include potential for ghost fishing from gear snagged on the cables and entanglement of marine mammals, and continual impacts to the seafloor and associated biota from strumming of unburied and suspended cable. Although there are ongoing impacts to sanctuary resources, of equal or more concern in the long term is disturbance anticipated in the foreseeable future associated with repair operations, which could result in multiple, recurring impacts.

Repair operations require cutting and lifting to recover the damaged cable from the seabed, splicing in additional cable, relaying the repaired cable on the seabed, and jetting to bury the repaired cable (see Section 6.4). Environmental impacts of repair operations include disturbance to the seabed from grappling for the cable, the cable being pulled from and dragged across the seabed during retrieval and re-installation, and jetting retroburial activities (see Section 6.4). The PC-1 cables, in their current condition, are at increased risk of multiple faults requiring repair operations at different locations and at different times.

7.1.3 Socio-economic Impacts (Alternative 1)

The PC-1 cables in their current condition cause a loss of fishing opportunity. Makah tribal longline and trawl fishers have reported they avoid fishing in the vicinity of unburied portions PC-1 cables because of increased risk of gear snag and loss (Tyler 2003). Loss of access to portions of the Makah Tribe's usual and accustomed fishing grounds infringes on the exercise of the Tribe's treaty fishing rights. Non-tribal commercial fishers, particularly trawlers, also avoid fishing in areas where unburied cable and obstructions have been identified since cable installation (Bob Briscoe, vessel captain, personal communication). In addition to the expense of replacing lost gear, fishers are concerned about the safety of their vessels and crew, as well as liability for damage to the cables. These concerns prevent the fishers from fully accessing productive portions of the open fishing areas, impact the fishers financially and concentrate fishing activity in other areas.

7.1.4 Estimated Area Affected (Alternative 1)

In essence, no area would be affected by remedial actions because no remediation measures would be implemented; however, ongoing disturbance is caused by unburied and suspended cables in OCNMS (Section 6.0). Out of approximately 105 km of total cable length in OCNMS, a minimum of approximately 2.4 km of PC-1 cables would remain unburied under Alternative 1, and of this 1.4 km would remain in suspension, unless natural processes act to further expose and

suspend or, alternatively, to ease suspensions and further bury exposed cable. A gross estimate of the seafloor area disturbed by cable strumming and potential movement across the seabed can be calculated as the product of the length of suspended and/or unburied cable (1.4 to 2.4 km) and the potential width of cable movement (roughly estimated at 5 to 30 cm), or an area between 70 and 720 m². In addition to seafloor disturbance, there are potential impacts of unburied and suspended cables to mobile fish and marine mammals associated with entanglement and ghost fishing, as described in Section 6.0.

In addition, a cumulative area could potentially be impacted during the anticipated service life of PC-1 cables by multiple repair operations distributed over space and time. Each time a cable fault occurs, repair activity will disturb an area of the sanctuary seafloor. The impacts at each cut and splice location includes disturbance from cutting the cable, recovery of the existing cable from the seafloor, and laying new cable onto the seafloor, and jetting to bury the cable. If an ROV is available, the area impacted by repair activity can be reduced by accurate location of the probable point of cable fault and use of the ROV to cut the cable. If an ROV were not available, shore based fault location would be used, which is less precise than ROV fault location, and grappling would be used to cut and retrieve the cable, which results in a larger area of seafloor disturbed than with ROV operations. The length of new cable inserted is a function of water depth and accuracy of the fault location. Assuming an average water depth of 250 m, a cable bight at least 1000 m in length would be surface-laid and then buried during PLIB operations at each repair location. This, in addition to the area disturbed by cable retrieval, yields an approximate total of 1.5 to 2 km of cable route and surrounding area that will be affected at the location of each repair site. Assuming an average impact swath of 1.5 m, a minimum total area of 2,250 to 3,000 m² of seafloor disturbance to roughly 1 m depth would occur at each cut and splice site. If grappling were used, the area of seafloor disturbance could be increased by roughly 600 m² or more.

7.1.5 Risks and Uncertainties (Alternative 1)

Under the No Action alternative, PC-1 cables present a safety risk to trawler vessels and crews operating near the area (see Section 5.5).

Uncertainties associated with the No Action alternative include 1) the potential for one or more cable fault(s) requiring repair, 2) the difficulty of completing a relatively rapid emergency repair that achieves appropriate cable burial, and 3) the feasibility of effective repair operations during inclement weather periods.

In its current condition, the cable has suspension nodes, frayed cable serving, and there have been incidents of gear entanglement. Under the No Action alternative, areas of unburied cable would remain as laid along both cable routes in OCNMS, and these conditions would remain, perpetuating a high degree of risk and uncertainty shared by the cable owners, NOAA, and tribal and commercial fishers.

NOAA seeks to avoid repeated disturbance to the seafloor and natural resources that would be caused by repair to suspended, unburied or shallow buried cable. Unfortunately, it is impossible to make a quantitative estimate of the timing or frequency of faults that might occur on the PC-1 systems in the sanctuary. For example, there is no simple method to calculate the time to failure

where a cable lies over a boulder without a thorough and repeated examination over time of chafe damage, which would be expensive in terms of funding and time and would result in a subjective interpretation. Basically, a cable fault could occur at any time. With a minimum cumulative distance of 30.2 km of PC-1 cables buried to less 0.6 m depth in OCNMS, there is considerable opportunity for faults to occur. After repairs at one location are completed, additional cable faults could occur at any time at other locations. Thus, the No Action alternative would not address these conditions. Given the high probability of multiple faults on the PC-1 cables in OCNMS, the cumulative area impacted by repair activities during the anticipated service life of the cables is of considerable concern to NOAA. As discussed in Section 7.4.5, there is also uncertainty concerning the number of repair splices that can be inserted without degrading the system performance.

If a fault in the cable does occur, the cable owner's primary goal would likely be to mobilize equipment and complete an emergency repair as soon as possible to minimize loss of revenue and transmission restoration costs. NOAA's interests are to minimize short- and long-term impacts to biological and cultural resources, as well as those of a recurring nature. Presumably, both parties will be interested in completing a repair that leaves the cable at low risk of repeated failure in the future.

Repair operations conducted on an emergency basis involve risks and uncertainties that could reduce the effectiveness of repairs. To complete a cable repair, the cable owner will require a window of suitable weather, as well as appropriate equipment and materials. The outer coast of Washington is subject to frequent inclement weather and severe storms that generate waves and swell of sufficient size to compromise the operations of cable repair vessels and in particular their ROVs, especially during winter months. Cable repair operations, though conducted from large vessels, can be limited by weather, sea, and swell conditions. In fact, poor weather conditions apparently were encountered during the installation of the PC-1 cables in OCNMS, which caused difficulties with control of residual tension on the cable and compromised cable burial to the target depth (ERM 2002). If the optimal cable repair vessel were dedicated to another operation, urgency to repair a cable fault, particularly after a delay for assembly of equipment and materials or with a limited period of vessel availability, could lead to selection of sub-optimal equipment (i.e., vessel, ROV, grapnels) or operations taking place during unfavorable weather conditions. It is not unlikely that the end result of an emergency repair could be an additional section of cable that is not sufficiently buried to adequately avoid further natural resource impacts and to effectively protect the cable against external aggression.

Another area of uncertainty is the feasibility of cable retro-burial at a repair site. A cut and splice repair operation requires inserting a length of excess cable that is typically laid out in a horizontal loop or 'bight' perpendicular to main cable route. The location of an emergency repair operation will be dictated by the location of the fault. Depending on the quality of available substrate characterization data, it may or may not be possible to accurately predict the feasibility of cable burial at a repair site, to select appropriate equipment for the site conditions, and to select the optimal route to maximize effectiveness of retro-burial operations. Consequently, the inability to predetermine the site of an emergency repair increases the risk that a repair will result in less than adequate cable burial. Some of this uncertainty can be reduced by conducting more thorough geophysical characterization of the cable routes, the information from which would be used to maximize the effectiveness of remedial actions.

7.2 Reduction of Selected Suspensions Without Splicing (Alternative 2)

Under Alternative 2, cable condition would be analyzed to identify areas of suspension with the greatest potential for user conflicts or the highest probability of cable fault based on the substrate type on which the cable rests, length and height of suspensions, and current or potential future fishing effort. Repair operations would be focused at a limited number of sites. After remedial actions are completed, some portions of the PC-1 cables in OCNMS would remain buried to less than 0.6 m, unburied, and suspended above the seafloor. This alternative would not fully address ongoing disturbance to sanctuary resources, the safety risks to fishers, the threat of multiple cable faults and resource disturbance from repair activities, full access to their U&A grounds by the Makah, or the objectives of the permit. Under this alternative, NOAA would amend the current Permit or issue a new permit to the cable owner.

7.2.1 Description of the Methodology (Alternative 2)

This remediation alternative involves conducting remedial actions at a limited number of locations, with the goal of reducing user conflicts and the number and severity of cable suspensions. This limited repair alternative would not involve cutting and splicing additional cable into the existing cable to reduce cable tension. Repair efforts could be directed at two types of suspensions: 1) the longest and highest suspensions; and 2) where the cables are suspended over boulders and hard substrate. In either case, the goal would be to lower the contact points at the nodes, or protuberances, which could allow the cable to relax toward the seabed where it might possibly be buried using an ROV equipped with a jetting tool. It would be necessary to employ a high powered jetting device to bury the cable due to the amount of sediment that would have to be moved to cover the cable under tension, thus causing substantial disturbance to the seafloor at and around the cable. Current jetting technology includes tools with 400 to 1,200 horsepower ratings (2 to 6 times the capability of the ROV used for initial PLIB operations) that are built to accomplish 2 to 3 m burial depth. ROVs can also be equipped with a suction dredge that can lift small gravel and discharge material to the side of a cable trench to improve burial depth. Reducing the height of contact nodes could be accomplished by repeated or high powered jetting of seabed, or by moving the cables off boulders, rocks and other seabed protrusions. Either action might allow the cable to settle and conform to the contours of the surrounding seabed. As an alternative or additional strategy, rock dumping could be conducted at these sites to add a protective layer of rock over the cable if the suspension is not high or on a steep slope.

In preparation for remediation actions, a remediation plan would be necessary to identify and evaluate potential work sites and provide a detailed description of the proposed methodology for each work site. Existing data on the location of problem areas and the slope and character of the adjacent seafloor may or may not be sufficient to develop a detailed remediation plan.

Analysis of cable condition data reveals that there are four sections of cable with intermittent or continuous suspensions that exceed 100 m in length (Appendix J, ERM 2002). If remedial repairs were limited to these longest suspensions and were successful in eliminating the suspensions or protecting the cable with a cover of rock, approximately 500 m in total length of suspensions could possibly be alleviated. High residual tension remaining in the cables, however, likely will limit the effectiveness of ROV jetting for cable burial at most sites (Wilson and

Darbyshire 2003). Therefore, even though some suspensions might be reduced, the cable could remain in suspension, unburied, or shallowly buried at portions of work sites.

A generalized methodology is as follows, with differing methods for soft and hard substrates. On soft seabed, a jetting ROV would be used to reduce the height of cable contact points at each end of the suspension. In such sediments, cable burial in excess of 0.5 m into the seabed might be achieved with multiple passes, if not precluded by high cable tension. In harder substrate (i.e., >50 kPa) or where a cable is suspended over solid obstructions like rock ledges or boulders, jetting ROVs are less effective, but it might be possible to move either the cable or boulder(s). If suspensions cannot be reduced by these methods, rock dumping could be used to deposit a protective layer over the suspended cable. This technology is further described in Section 7.3. The feasibility of rock dumping for long-term cable protection depends on several factors, including the stability of sediments at the site, the frequency of area use by bottom trawlers, the slope of the seafloor, the type of submarine cable, and the height of the suspension. Although no definitive criteria were identified for this document, rock dumping might not be appropriate in areas of mobile sediments or where the slope would cause rock to slide off the cable. An industry representative indicated that the technique has been used on slopes of about 45° but site-specific analysis is required (Rene van Kessel, Van Oord ACZ Offshore, personal communication, 10/31/03).

7.2.2 Impacts to Natural Resources and Seafloor (Alternative 2)

The remedial actions proposed to alleviate suspensions under Alternative 2 would result in considerable disruption to the seabed at the nodes adjacent to the suspensions and along the routes where retro-burial is attempted. The jetting ROV would liquefy seafloor sediments under the cable, causing displacement of sediments, alteration in substrate composition, and injury or mortality of sessile organisms (see Section 6.4). There are no identified studies that assess recovery of the biological community following jetting disturbance of soft bottom habitat at depths found on PC-1 routes in the sanctuary. Limited NOAA monitoring of PLIB areas has shown that jetting in coarse sediments alters the substrate considerably from undisturbed areas nearby and these effects remain for years afterward (see Section 6.4). Shifting the cable off obstructions such as rocks or boulders would likely scrape and damage encrusting organisms on rocky substrate. Organisms could also be damaged when rocks are rolled or moved during remedial operations. Deep sea organisms found attached to hard substrate are generally long-lived and fragile, and their recovery could be considerably slower than that of organisms found in soft substrate (Watling and Norse 1998).

Rock dumping would cause substantial habitat alteration where employed (see Section 7.3.2). Because such alteration of the seabed and placement of material on the seabed are prohibited activities within the sanctuary, this remediation approach would require site-specific analysis. Rock dumping would not be considered by NMSP an appropriate method for long cable segments due to the area affected by habitat alteration.

Ongoing impacts would be reduced to the extent that remediation operations are successful in retro-burial of cable at sites of suspension. Because of the high number and widespread distribution of suspended PC-1 cable sections in OCNMS, however, the proposed remediation actions under this alternative could not address all these sites and would not alleviate or reduce all

suspensions. The ongoing environmental impacts of unburied cable that remains after limited repair remediation operations would be similar to those described under the No Action alternative. In the long term, the environmental consequences and uncertainties associated with remaining suspensions and unburied cable include the distinct risk that a cable fault would occur and require one or more repairs due to physical wear and damage from natural or anthropogenic causes.

7.2.3 Socio-economic Impacts (Alternative 2)

Because this remediation alternative has limited ability to improve the burial status of the PC-1 cables (see Section 7.2.5), the socio-economic impacts of Alternative 2 would be essentially the same as those described for Alternative 1. It is uncertain how berms created by rock dumping would impact bottom contact fisheries and the benthic community (see Section 7.3.3) although proponents of this technology indicate that berms can be traversed by trawl gear and are resilient to repeated trawl passes, which implies that trawlers would not be negatively impacted by the presence of the berms.

7.2.4 Estimated Area Affected (Alternative 2)

An estimate of the area affected is impossible to make before a remediation plan is developed that identifies and characterizes sites with best likelihood of success.

7.2.5 Risks and Uncertainties (Alternative 2)

Each repair approach described in Section 7.2.1 is possible in theory. However, success with ROV jetting is questionable due to the high residual tension in the PC-1 cables. Video logs reveal that some of the suspensions are in areas where the cable lies above or within a visible trench, and no seafloor features are present to provide suspension nodes (Appendix J, ERM 2002). Three of the four longest suspensions are located at sites where PLIB operations already made repeated passes with a jetting ROV in an unsuccessful attempt to bury the cables. Two of these long suspensions are associated with PLIB site E3 and one with site E2 (ERM 2002). The one long suspension not associated with a PLIB site was attributed by contractors for Global Crossing to an area of undulating seabed in combination with a transition from sand to gravel/boulder seafloor (p. 6-30, ERM 2002). It is possible that this one suspension could be reduced by jetting, yet residual tension likely would limit effective cable burial. In practice, however, there are several inherent risks and limitations with these activities, regardless of the residual tension.

1) The degree to which a cable suspension can be alleviated without cutting the cable is dependent upon the ability to reduce the height of contact nodes, as well as availability of sufficient slack and lack of high residual tension in the cable to allow the cable to relax downward against and into the seabed. If the contact nodes can be reduced to a sufficient height by jetting or by moving the cable off an obstruction(s) and the cable has sufficient slack, a suspension can be significantly reduced or eliminated. If either of these elements is missing, efforts to reduce suspensions will be less effective.

- 2) Jetting is unlikely to be successful for alleviating suspensions over hard seabed where sediments cannot be softened under the cable, or where slopes are substantial or the residual tension is high.
- 3) The length of seabed subject to ROV jetting at the node(s) will depend upon the length and height of the node relative to the surrounding seabed. If the nodes are long (e.g., >10 m) and high (e.g., >0.5 m) above the surrounding seabed, it might not be feasible to successfully lower the cable height sufficiently to eliminate some or all of the cable suspension.
- 4) The residual tension evident on PC-1 cables in OCNMS likely would prevent cable burial unless the cable was cut to provide additional length and introduce slack, thereby reducing residual tension.
- 5) Suspensions caused by cable laid over hard obstructions, such as a boulder or rock, might not be eliminated if the obstruction cannot be moved or if the cable cannot be shifted off the obstruction. ROVs are not typically designed for this type of operation. Although such operations could be attempted, the ROV could be damaged in the process, and the operators or associated insurers of the ROV could raise objections to this type of use.
- 6) Attempting to move a fiber optic cable off a resistant object, such as a boulder, using an ROV could result in damage to the cable, particularly if there is insufficient slack and the cable itself resists the attempt to move. Moreover, if an optical amplifier or splice box lies close to the proposed ROV work site, it is likely that either the manufacturer or the cable owner will have strong concerns about the integrity of these expensive components during such remediation operations.
- 7) The feasibility of rock dumping to provide cable protection in areas with suspended cable will require analysis of site characteristics (i.e., sediment mobility and slope) and risk of damage to the cable from the impact of rock delivered from the fall pipe from a height of 100 to 300 m.
- 8) Reduction of nodes in areas of active sediment transport, such as sand waves, is likely to be a temporary solution. Unless the cables can be buried below the active layer of sediment throughout an area of sand waves, new suspensions of cable can form as sediments erode to expose cable (Allan 2000), and because the cable is under tension, this is unlikely to work.

The highest probability of success with Alternative 2 appears to be with rock dumping or a reduction of physical damage to the cables from abrasion where they lie against boulders. It is possible that other sites where jetting has not previously been attempted could be selected for remedial operations.

Ultimately, this remediation alternative leaves numerous areas where the PC-1 cables present a safety risk to fishers and cables are at risk of external aggression. Even if the 4 longest suspensions and 9 cable suspensions over boulders noted in ERM reports were eliminated, remediation under Alternative 2 would leave numerous sections unburied on the seafloor and about 30% (by length) of the PC-1 cables in OCNMS buried shallower than the target burial depth. Nearly 100 shorter sections of suspended cable (about 90% of cable suspensions by

number) would remain spanning about 0.8 km of seafloor. In addition, about 75% of the existing unburied cable (by length) would remain, and at least 29.6 km of unburied and shallowly buried cable would not be addressed under this remediation alternative. This alternative would not fully address ongoing disturbance to sanctuary resources, the safety risks to fishers, the threat of multiple cable faults and resource disturbance from repair activities, full access to the U&A fishing grounds, or the objectives of the permit. Under this alternative, NOAA would amend the Permit or issue a new permit to the cable owner.

7.3 Protective Rock Cover (Alternative 3)

Under this alternative, rock would be used to cover the cables where there is risk of external aggression to the cable due to inadequate burial. A protective cover of rock, a process referred to as “rock dumping” by industry, could be provided wherever the cables are shallowly buried, unburied, or suspended throughout the sanctuary. After successful remedial actions are completed, risk of external aggression to the cables would be reduced or eliminated where applied for as long as the rock placement itself is stable. If the rock berms created did not interfere with bottom contact fisheries, the safety risk and area use loss for fishers could be eliminated. Because extensive areas of the cable routes would require such protection, there would be long-term alteration of seafloor habitat to an extensive area, the effects of which are difficult to anticipate and characterize. Expectations are that fine sediments adjacent to the rock berms would be winnowed away in a manner similar to areas currently along the cable where rock piles are found with sparse fine particulates between larger components. Under this alternative, NOAA would amend the current Permit or issue a new permit to the cable owner.

7.3.1 Description of the Methodology (Alternative 3)

Rock dumping involves placement of rock along a route using a vessel fitted with a flexible fall pipe to deliver material to the seafloor. Graded material of 2.5 to 13 cm (1 to 5 in.) is typically used at a rate of approximately 4 tons per meter berm length. A suspension 0.5m high would require about twice this amount. This technology has been used from shore to depths of greater than 600 m to provide protective fill material over exposed submarine installations, typically pipelines but occasionally submarine cables. Typically, a site-specific route survey in advance of operations is necessary to assess the applicability of this technology at target locations and plan accurate placement of rock material. Post dump surveys are employed to evaluate the initial effectiveness of operations. An alternative technique is concrete mattresses that are laid atop unburied pipelines or cable to provide protective cover. Although this approach might be feasible, it is impractical because of the large extent of areas requiring added protection, the number of mattresses, and the ROV time that would be required. For example, mattresses are typically about 2.5 m long, so 100 mattresses would be needed to cover a 250 m section of unburied cable. Because each mattress is individually carried and positioned on the cable route by an ROV, the labor effort to protect only limited portions of PC-1 cables would be extensive.

To achieve cable protection as specified in the Permit and industry standards for both cable routes in OCNMS, rock dumping would be required along at least 15.4 km of PC-1 East and 16.1 km of PC-1 North, or a cumulative distance of at least 30.2 km in the sanctuary. Lack of cable burial depth data and/or video coverage for 9.2 km of PC-1 East and 2.1 km of PC-1 North makes it impossible at this time to determine the need for remedial measures at these areas.

7.3.2 Impacts to Natural Resources and Seafloor (Alternative 3)

Dumping of large volumes of rock on unburied cable would appreciably alter the habitat along the cable routes and would bury the existing benthic community over a swath conservatively estimated at 3 m wide. Although portions of the cable route have surface substrates that include gravels, cobbles, and scattered boulders, fresh deposits of rock taken from a land source and processed, crushed and graded to appropriate specifications for rock dumping would not resemble natural substrates on the cable routes. Extensive distances along the cable routes would require rock dumping to achieve cable protection, which would create unnatural linear features on the seafloor. These rock berms likely would alter sediment dynamics in areas of mobile sediments, and result in local deposition and/or erosion that could impact the effective durability of the rock cover. The impacts on fish of rock berms as artificial habitat are uncertain, and it cannot be assumed that such features would enhance fish habitat. Given these anticipated environmental impacts, rock dumping seems most appropriately applied on a localized basis, to reduce fault risk and/or user conflicts at selected and relatively small areas, and in combination with other remediation approaches (see Alternative 2). Because alteration of the seafloor and discharge of material are prohibited activities in OCNMS, a permit would be required for this work.

7.3.3 Socio-economic Impacts (Alternative 3)

Rock dumping creates features on the seafloor that could allow trawlers to traverse a cable route without damage to fishing gear or risk of snagging gear according to Van Oord ACZ Offshore, the world's largest practitioner of this technology (Rene van Kessel, personal communication, Van Oord ACZ Offshore). If trawl gear were able to ride up and over the rock berm, there could be no negative impact to trawlers under this alternative based on loss of area use. However, the fishing industry has complained about underwater rock berms as a hazard to trawlers due to damage to nets traversing the berms and filling of nets with rock to make nets heavy and possibly a hazard to vessel safety (van Elsen 2001). Long line gear could snag on an unconsolidated rock berm, but given the small size of graded material used it is unlikely that long line fishers who set gear in the area would experience gear loss.

7.3.4 Estimated Area Affected (Alternative 3)

The rock deposit would likely cover a swath conservatively estimated at 3 m wide. If remedial operations addressed all known areas of shallowly buried, unburied, and suspended PC-1 cables in the sanctuary (minimum cumulative distance of 30.2 km), the area of altered habitat would be $\geq 90,600 \text{ m}^2$ or $\geq 0.09 \text{ km}^2$.

7.3.5 Risks and Uncertainties (Alternative 3)

Several considerations require further analysis before the risks, uncertainties, and technical feasibility of this cable protection method can be addressed. LWA cable could be damaged by this technique. Rock dumping through a free-fall pipe approximately 1 m wide from a height of 100 to 300 m would deliver material at considerable force to the seafloor. The terminal velocity of the rocks and the angular shape of hard material could cause physical damage to exposed LWA cable, although practitioners claim materials could be deposited immediately adjacent to the cable and a berm built without direct deposition on exposed cable. For example, it is uncertain if placement of rock could be accomplished precisely enough to avoid physical and abrasive damage to LWA cable suspended under tension over a boulder at a height of 0.3 m above the seafloor.

The technical feasibility and long-term effectiveness of this technology at target locations in the sanctuary would also require careful analysis. Some areas of poorly protected PC-1 cables are associated with steep slopes where rock deposits would not be stable in the long term. If rocks were displaced from their original placement or moved down slopes by gravity, currents or repeated passes of trawl gear, the initial protection provided the cable would be reduced over time. A related issue is that local slopes can be much greater than indicated in existing bathymetry because seafloor slopes are calculated with considerable averaging during data acquisition and processing. As a result, rock may be unstable at localized areas of steep slopes. Another question is the persistence of rock material deposited in areas of unstable sediments. Sand waves of 1-m amplitude were identified in several areas along the PC-1 routes in the sanctuary, and larger sand waves reached 15 m in height. These seafloor features indicate mobility associated with near bottom currents that could affect the long-term stability of a rock berm. If sediment adjacent to the rock berm were eroded away (a common effect with rock placement for shoreline stabilization), the rock would likely slough down into these adjacent troughs and reduce the effectiveness of cable protection.

Another technical uncertainty with rock dumping is feasibility of operations in areas where subsurface currents are relatively strong. Unpredictable water column and near bottom currents at the eastern end of the cable routes in OCNMS have prevented ROV operations in the area for video survey and cable burial depth measurement. During NOAA surveys, these currents have been estimated at roughly 3 knots near the seafloor by ROV operators. The ROV at the termination of the fall pipe would require adequate power to hold position over and navigate across the seafloor while working against the force of water column currents acting on 100 m or more of 1-m diameter fall pipe. Vessel owners claim to have worked in areas 600 m deep with currents of up to 6 knots ((Rene van Kessel, Van Oord ACZ Offshore, personal communication, 10/31/03).

As noted above, rock berms could be undesirable and present a hazard to bottom trawlers if rocks are entrained in nets. A mixed catch of rocks and fish is more difficult to sort, and damage from rocks could reduce the market value of the fish. Also, if sizeable quantities of rock are picked up by trawl nets, the vessel and crew can be at risk if retrieval of gear is complicated by the weight. In fact, there is a reported incident of a fishing vessel loss for this reason (van Elsen 2001). Application of a coarser rock followed by finer rock to fill the interstices can reduce this risk and uncertainty.

The scale of effort required to adequately protect approximately 30 km of PC-1 cables in the sanctuary is potentially enormous. For example, a pipeline project in Australia roughly one quarter this size required construction of a rock load-out facility to service the project. It is uncertain if the quantity of rock is readily available at a shore-based facility in the region where it can be transferred directly to the dumping vessel, or first to a barge and then transferred to the dumping vessel.

7.4 Repair by Splicing and Retroburial (Alternative 4)

This remediation alternative would attempt to alleviate most or all suspensions and current unburied sections of the PC-1 cables by inserting sections of new cable to reduce cable tension and possibly altering the cable route in limited areas to seabed more conducive to cable burial. Improved cable protection would be achieved by 1) reducing or eliminating most or all cable suspensions and unburied sections, 2) improving cable burial depth where less than 0.6 m was achieved, or 3) replacing the LWA cable with more heavily armored cable in areas where sediments are not conducive to cable burial and a re-route with burial cannot be accomplished. If used, the heavier armored cable would remain exposed on the seabed. If successful, this alternative would eliminate ongoing disturbance to sanctuary resources and the risks to fishers, and reduce the threat of future cable faults and resource disturbance from repair activities. Under this alternative, NOAA would amend the Permit or issue a new permit to the cable owner.

7.4.1 Description of the Methodology (Alternative 4)

The installation of additional cable to introduce sufficient slack and reduce high residual tension for remediation of most or all existing unburied cable would require a similar methodology for each splice. A brief description of the methodology follows.

- 1) Develop a remediation plan to analyze options and identify the most effective locations for cut and splice operations. The remediation plan also must consider the option of replacing the LWA cable with single armor heavy or double armor cable in limited areas.
- 2) Mobilize necessary cable and splice boxes onboard a cable repair ship equipped with a jetting burial ROV and implement repairs. The repair operation entails using an ROV for cutting and recovering the existing cable at point(s) along each suspension or at one of the nodes on a suspension. One end of the cable is brought to the surface onboard the repair vessel and buoyed off. The repair vessel then recovers the other end of the existing cable, brings it to the surface, splices on the extra cable, lays in the extra cable to the buoyed off end and makes the final splice. The repair vessel then lays the new cable out perpendicular to the existing cable on the seabed (a bight), followed by the jetting ROV to bury the added cable, splice boxes and any adjacent unburied sections of the existing cable. Ideally, these sites are selected where soft sediments are conducive to retroburial, but at locations where post repair burial might be considered to be difficult or impossible, a heavier armored cable type would be used. The cable ship lays the cable out perpendicular to the original cable in a semi-circle, followed by an ROV survey to ensure no standing loops were created. These procedures are repeated at each repair location.

7.4.2 Impacts to Natural Resources and Seafloor (Alternative 4)

The environmental consequences of Alternative 4 would include impacts to soft and hard bottom habitats from grappling, cutting, retrieving existing cable, relaying splice boxes and additional cable, and jetting to bury added cable sections. These impacts are described in more detail in Section 6.4. If unburied, heavy armored cable were used at repair sites, disturbance at re-installation by jetting would be avoided, but the unburied cable could cause seafloor disturbance and ghost fishing impacts.

7.4.3 Socio-economic Impacts (Alternative 4)

If this alternative were technically feasible, remediation efforts could eliminate suspensions, unburied, and shallow buried cable, reduce fishing gear entanglement risks, and open areas to fishing. Because Alternative 4 is considered technically impractical with very limited ability improve the burial status of the PC-1 cables, the socio-economic impacts of its implementation would be essentially the same as those described for Alternative 1 in Section 7.1.3.

7.4.4 Estimated Area Affected (Alternative 4)

Multiple repairs would be required under Alternative 4, and the cumulative area disturbed by these repairs could exceed that of other remediation alternatives that have greater probability of success (i.e., cable burial to ≥ 0.6 m, reduction in future risk of cable fault, and minimization of ongoing impacts).

7.4.5 Risks and Uncertainties (Alternative 4)

In recent years, repair operations on submarine fiber optic cables have been implemented to relieve suspensions or to relocate unburied cables from areas with active bottom contact fisheries, for example, the PC-1 cable in Canadian waters and the Southern Cross cable in Oregon (Wilson and June 2002). However, these repair operations addressed limited locations along the cables. Cable suspensions on the PC-1 routes in OCNMS are numerous, widely distributed, and interspersed with areas of buried cable or cable exposed on the seabed (Figure 1). Also, a limitation of this approach is that high residual tension will be relieved only in the immediate vicinity of a splice. Consequently, remedial repairs under Alternative 4 would necessitate a major repair effort, would involve a large number of splices, and would result in additional cable length at numerous locations. From the cable engineering and system performance perspective, this remediation alternative is impractical. Moreover, there is risk that the cable repair operations could introduce new problem areas given the number of bights that would be added and jetted to accomplish the numerous repairs.

Engineering considerations limit the number of splices that can be inserted into a fiber optic cable. According to typical cable manufacturer's guidelines, there are a finite number of splice boxes (where two ends of cable are connected) and cable lengths that an amplified or repeatered system, such as the PC-1 cables, will support between any two amplifiers. This is because each additional length of cable and splice introduces a signal level loss along the fiber and at the fiber splice. Repeaters, or amplifiers, are placed approximately every 50 km along the PC-1 cables. Each repair would require two splice boxes. The addition of the numerous splice boxes required

to adequately remediate the PC-1 cables in OCNMS would degrade the cables' ability to operate properly to the extent that one or more extra optical amplifiers may be required. This is unacceptable from an engineering perspective. To avoid this problem, a replacement cable section of substantial length containing no splice boxes could be installed. However, given the widespread distribution of problem areas, this approach approximates Alternative 5.

A characteristic of any repair is that it will introduce additional cable length into the system, at a minimum two times the water depth at the site. Normally, this additional cable, called a bight, is laid out perpendicular to the original cable route to prevent "doubling over" of the cable (i.e., laying of cable back over itself). If LWA cable were used, each bight would require burial by jetting ROV to protect against external aggression. If numerous splice repairs to the cables were implemented, the net effect would be a cumulative length of cable perpendicular to the cable route that could exceed the length of the original cable route in the sanctuary. Moreover, these remediation actions might not reduce the risk posed by the extensive portions of the PC-1 cables that would remain shallowly buried in OCNMS.

From a cable engineering standpoint, a heavier armored cable offers the advantage that post-lay burial of cable would not be required. Nevertheless, besides reduced impacts of cable burial during installation, the same engineering limitations described above for LWA cable apply to heavier armored cable. An unburied, heavier armored cable is designed to be less susceptible, but not impervious, to external aggression from fishing gear (Hoshina and Featherstone 2001). In addition, any surface-laid cable can cause seafloor disturbance and presents a risk that fishing gear can be snagged, which is a safety hazard as well as a potential cause of gear loss, ghost fishing, and disturbance to the seafloor.

The repair procedures suggested by this remediation alternative have been developed to repair individual cable faults, but they are not practical for repair of numerous problem areas distributed throughout the length of the cable route. Consequently, this remediation alternative is technically possible but untenable and impractical with either buried LWA or surface-laid heavy armored cable.

7.5 Repair of Large Problem Areas (Alternative 5)

Identified areas where cable protection is compromised by lack of cable burial, shallow burial depth and cable suspension over boulders are clustered into three major sections of each PC-1 cable. Remedial operations would focus on these three areas on each cable route and include recovery of existing cables, reinstallation with plow burial to $\geq 0.6\text{m}$ and retro-burial by ROV jetting at bights. Modifications to the existing cable routes could be recommended to maximize potential success of burial operations. Under this alternative, NOAA would amend the Permit or issue a new permit to the cable owner.

7.5.1 Description of the Methodology (Alternative 5)

Nearly all locations that are not installed to $\geq 0.6\text{ m}$ depth in the sanctuary can be clustered into three major areas, roughly at the eastern and western ends of the routes and the middle section of each cable (Figure 1). This is true for both the PC-1 North and East cables, although the boundaries or extent of these "problem areas" may not align precisely on the two cable routes.

Under Alternative 5, three separate cut and splice operations would be conducted on each cable to remove poorly protected cable sections and re-install cable with burial using a plow.

Analysis of cable condition would be required to define the boundaries of targeted areas and characterize areas where existing cable burial data is lacking. For example, there is not TSS data for cable burial depth on PC-1 East for approximately 6.6 km at the eastern end and 1.4 km at the western end. In both places, surveys using cable tracker technology (e.g., TSS 350) would be conducted to determine cable burial depth and accurately define the full extent of target areas. If one were to assume that substrate and installations were similar between the two PC-1 cables in these areas, the substantial lengths of PC-1 North buried <0.6 m indicate that reinstallation is advisable on PC-1 East also.

The following steps would be required at each target area to accomplish Alternative 5.

- 1) Develop a cable remediation plan to evaluate the feasibility of successful burial of cable to at least 0.6 m, determine if and where additional data were required to complete this evaluation, identify and address any obstacles to cable installation, recommend a preferred route for the cables at each target area, identify areas where a preferred route differs from the existing route and areas where re-routing of the cable is necessary to avoid obstacles to burial, and identify the optimal time window for completing remedial operations.
- 2) Mobilize vessels for ROV support and cable installation, with sufficient replacement cable, splice boxes, and repeaters.
- 3) To minimize disturbance to the marine habitat within the sanctuary, begin the cable recovery by grappling or ROV where the cable is cut, sealed, and one end is buoyed off. Station a guard ship to protect the buoyed end of the cable. Final bights, where PLIB operations and jetting is required, would be located where sediments are conducive to retroburial by jetting to maximize burial depth.
- 4) Commence recovery of the cable through a targeted section to a position at the far edge of the targeted section, where the second cable cut is made.
- 5) Make the initial splice between the original and new cable. Launch the plow and proceed with replacement cable re-lay through the targeted section towards the buoyed end.
- 6) Initiate monitoring of plow performance and cable burial condition using a support vessel with ROV stationed at a reasonable distance from the installation vessel. Any problems in the lay (e.g., suspensions, other effects of high residual tensions, shallow burial, etc.) will be reported immediately, and there would be an attempt to rectify the problem through plow recovery and re-installation, if appropriate.
- 7) At the far end of the targeted section, recover the plow, recover the buoyed end, and complete the final splice of the cable end.
- 8) Lay out the final splice bight perpendicular to the cable route and bury with the jetting ROV.

- 9) As a final step, complete an ROV survey with a cable tracking device (e.g., TSS 350) and video to evaluate and/or confirm cable burial depth and seafloor condition over the entire length of the new installation.
- 10) Because a substantial length of the cable would be replaced, long-term post-installation inspection and benthic monitoring would be implemented.

7.5.2 Impacts to Natural Resources and Seafloor (Alternative 5)

Remedial actions under Alternative 5 are expected to have short term environmental consequences at targeted areas (see Section 6.4), and the potential long-term impacts (see Section 6.0) would be greatly reduced if effectively protected cables were achieved, as compared to the No Action Alternative.

Initially, the recovery of the existing cables would cause environmental impacts along the original cable routes, as described in Section 6.4. Seafloor disturbance would be minimized if ROV cut and recovery procedures are utilized, or the distance the cutting grapnel is dragged could be minimized if the cables are first located precisely with an ROV. At four of the six required cable cut locations on each cable, operations could be located outside OCNMS boundaries to avoid impacts to sanctuary resources if governments with authorities over these areas (i.e., Canada and the State of Washington). Where the existing cables are buried, the sediment, infauna, and epifauna would be disrupted as the cables are lifted. If the cable retrieval vessel is not precisely over the cable route, some lateral movement of the cable along the seabed (e.g., several meters) would occur prior to its lifting off the seabed, which would disrupt the seabed to a depth of a few centimeters. Where a cable crosses hard bottom habitats, some damage to encrusted and attached biota can be expected as the cables are lifted off the seabed. In areas where particularly stiff sediment offer higher protection against external aggression, a somewhat reduced burial depth may offer adequate protection. Organisms could also be damaged when rocks are rolled or moved during the remediation operations.

Other than NOAA studies of the PC-1 routes, there are no identified studies that assess the recovery following plow burial or jetting disturbance of soft bottom habitat at depths found on PC-1 routes in the sanctuary. General comments on findings from NOAA monitoring surveys are provided in Section 6.4. The general assumption is that the seafloor and associated biological community should recover to a comparable state within the time frame of several months to several years. Deep sea organisms found attached to hard substrate are generally long-lived and fragile, and their recovery could be considerably slower than that of organisms found in soft substrate (Watling and Norse 1998).

7.5.3 Socio-economic Impacts (Alternative 5)

The adverse socio-economic impacts associated with shallowly buried and unburied PC-1 cables described in Section 7.1.3 would be largely eliminated under Alternative 5. Cable burial to ≥ 0.6 m depth would allow Makah fishers to fully access their U&A fishing grounds and all commercial fishers to operate throughout open fishing areas without an elevated safety risk. All alternatives would entail short-term impacts to fishers if repair and/or remedial actions occurred during fishing seasons because fishers would be temporarily excluded from operating in the

vicinity of a cable repair vessel. This area exclusion, however, would be on the order of a few days as opposed to 25 years, the duration of the cable service life, for the area exclusion that currently exists due to unburied and suspended cable.

7.5.4 Estimated Area Affected (Alternative 5)

An accurate calculation of area affected could require further survey to determine the extent or boundaries of targeted areas. Nevertheless, if targeted areas are extended to the sanctuary boundaries, the east, mid, and western target areas on PC-1 North are approximately 14.3 km, 15.5 km, and 3.7 km, respectively, for a total of 33.5 km. On PC-1 East, east, mid, and western target areas are approximately 14.1 km, 15.2 km, and 5.4 km, respectively, for a total of 34.7 km. Seafloor disturbance would result from both recovery and installation phases of the remedial operations but these would be one-time, short duration events. Modern navigation equipment allows a ship to lay a cable within 5 to 10 m of the planned route (Drew and Hopper 1997, Mike Wilson, PICC, personal communication). Although old and new cable paths may intersect and be quite close, it is likely that different areas of the seafloor would be disturbed by each phase of the operations. To the extent that these occur precisely in the same location, the area disturbed can be reduced.

Impacts from removing the existing cable include the action of the cable being pulled from the sediment and disruption of the seabed to a depth of 1-2 cm over the distance the cable is dragged along the seabed prior to being lifted off the seabed (e.g., less than 10 m). Impacts from burial of replacement cables would cover a path the full width between the skids of the seaplow (or 5.1 m on the Seaplow 8 currently proposed by PCL and Tyco for remediation operations), although the most severe impacts would occur over a path about 3 m wide where the plowshare disturbs the sediment (as observed from monitoring of existing PC-1 cable routes). Assuming that cable recovery disturbs a 1 m wide path, the area impacted by cable recovery is at roughly 68,200 m² (0.06 km²). Reinstallation could disturb an area of roughly three to six times this. Thus, the cumulative area disturbed by complete reinstallation would be roughly 0.2 to 0.6 km² (204,600 to 613,800 m²). Jetting would be required to bury surface-laid cable at each cable bight and each cable crossing, which is factored into the estimate of area disturbed. If grappling was used to cut and retrieve the cable, a larger area of seafloor would be disturbed by the grappling activity. If cable retrieval operations and splices were located outside of OCNMS boundaries, the area affected within OCNMS would be reduced. This would not reduce the impacts themselves, however; impacts could be displaced to areas under another management authority (e.g., Canada on the west end of the cable routes). Between 4 and 6 splice and bight areas on each cable with associated PLIB impacts on the seafloor and natural resources would be required in OCNMS, depending on this latter consideration.

7.5.5 Risks and Uncertainties (Alternative 5)

Risks associated with the Alternative 5 are minimal, granting the assumption that plow burial of cable could more successfully achieve target burial depth than the initial installation provided. The advantage of this alternative is that cable reinstallation can be planned and implemented in a manner that minimizes the risks and uncertainties of successful remediation associated with route selection for optimal burial feasibility, weather conditions, and vessels and equipment availability. A thorough re-analysis of cable routes would be required to select optimal routes to

facilitate achieving cable burial through the targeted areas. Where seafloor substrate characterization is insufficient, additional survey work would be required to assist with optimal route selection. Operations would be required to be scheduled to take advantage of optimal weather periods and to avoid periods when severe storms are frequent and could compromise the success of cable burial. Time would be available for advance planning and scheduling of appropriate equipment. Use of an ROV to conduct ‘real time’ monitoring of the installation as it occurs would minimize suspension and/or exposure problems similar to the original cable installation. In recent years, this technique has been effective in producing successful cable installations off Oregon and California.

Under Alternative 5, the susceptibility of cables to external aggression and risk of a cable fault is dramatically reduced in comparison to the status quo, as is the risk that fault repair operations in the future will disturb the sanctuary’s natural resources. Ongoing impacts and threats to natural resources from unburied and suspended cables are expected to be eliminated completely.

Where the final bights of the cable splices are surface laid and jetted for burial, cable burial to 0.6 m or more might not be achieved. PLIB operations would also be required at cable splice points where plow installation is initiated. There would be between 4 and 6 PLIB sites on each cable in the sanctuary, depending on approvals to locate these operations beyond sanctuary boundaries. These PLIB sites would be in areas open to Makah bottom trawlers, except perhaps those at the western end if they were located in Canadian waters. Therefore, under this alternative there could be areas of shallowly buried cable at the PLIB sites where both the cables and fishers are at some risk of interaction.

There are potential engineering risks associated with multiple cut and splice repair locations (i.e., signal degradation) that would require analysis by a professional cable engineer.

7.6 Complete Recovery and Reinstallation with Cable Burial (Alternative 6 - Preferred)

This alternative entails complete recovery of existing PC-1 cables within OCNMS and reinstallation that optimizes cable burial to ≥ 0.6 m depth, with greater attention to for route selection and installation procedures than were used for the initial installation. Improved characterization of the seafloor in certain areas might be required to make an effective assessment of burial feasibility near existing routes, with potential modifications to existing routes. This alternative would fully address ongoing disturbance to sanctuary resources and the risks to fishers, and substantially reduce the threat of future cable faults and resource disturbance from repair activities. Under this alternative, NOAA would amend the current Permit or issue a new permit to the cable owner. This is NOAA’s Preferred Alternative and ACOE’s Proposed Alternative.

7.6.1 Description of the Methodology (Alternative 6 - Preferred)

Alternative 6 entails the same basic methodology described for Alternative 5 (see Section 7.5.1) applied once for each PC-1 cable along the entire route within OCNMS. The cable owner (Pacific Crossing Ltd. or PCL) and the contractor for the cable’s original installation (Tyco Telecommunication (US) Inc. or Tyco) have indicated that they will accomplish the cable

remediation based on a remediation protocol and plan that would implement NOAA's Preferred Alternative and the ACOE's Proposed Alternative.

7.6.2 Impacts to Natural Resources and Seafloor (Alternative 6 - Preferred)

Remedial actions under Alternative 6 are expected to have environmental consequences similar to the initial installation of the PC-1 cables through OCNMS and repair operations associated with cable cutting and recovery, plow installation, and localized PLIB operations, as described in Sections 6.4. Alternative 6 would require four splice locations (two on each cable segment), which might be located outside the sanctuary if adjacent authorities approve.

The long-term impacts of leaving the reinstalled cables in place, however, would be reduced were NOAA to implement Alternative 6, as compared to the No Action Alternative. Ongoing impacts and threats to natural resources from unburied and suspended cables are expected to be eliminated completely.

7.6.3 Socio-economic Impacts (Alternative 6 - Preferred)

The adverse socio-economic impacts associated with shallowly buried and unburied PC-1 cables, as described in Section 7.1.3, would be eliminated under Alternative 6. Cable burial to ≥ 0.6 m depth would allow Makah fishers to fully access their U&A fishing grounds and all commercial fishers to operate throughout open fishing areas without an elevated safety risk. All alternatives would entail short-term impacts to fishers if repair and/or remedial actions occurred during fishing seasons because fishers would be temporarily excluded from operating in the vicinity of a cable repair vessel. This area exclusion, however, would be on the order of a few days as opposed to 25 years, the duration of the cable service life.

7.6.4 Estimated Area Affected (Alternative 6 - Preferred)

As currently routed, each cable extends over 50 km across the sanctuary for a cumulative length of approximately 105 km of PC-1 cables within OCNMS. Seafloor disturbance would result from both recovery and installation phases of the remedial operations but these would be a one-time, short duration event.

The area impacted by cable removal, plow installation and PLIB operations is similar to that for Alternative 5 (see Section 7.5.4) except the total distance of the plow route is approximately three times larger while the extent of PLIB impacts is approximately one third under Alternative 6. Assuming that cable recovery disturbs a 1 m wide path, the area impacted by cable recovery is at roughly $105,000 \text{ m}^2$ (0.1 km^2). Reinstallation could disturb an area of roughly three to six times this. Thus, the cumulative area disturbed by complete reinstallation would be roughly 0.3 to 0.6 km^2 ($300,000$ to $600,000 \text{ m}^2$). Jetting would be required to bury surface-laid cable at each cable cut and splice site and each cable crossing, but this is factored into the estimate of area disturbed. If grappling was used to cut and retrieve the cable, a larger area of seafloor would be disturbed by the grappling activity. Locating the cable retrieval operations and splices outside of OCNMS boundaries can reduce the area affected within OCNMS. These impacts, however, could be displaced to areas under another management authority (e.g., Canada on the west end of the cable

routes). Depending on this latter consideration, between 0 and 4 splice and bight PLIB operations would be required in the sanctuary.

7.6.5 Risks and Uncertainties (Alternative 6 - Preferred)

Minimal risks are associated with this alternative, which has a distinct advantage in that cable reinstallation can be planned and implemented in a manner that minimizes the risks and uncertainties of successful remediation associated with route selection for optimal burial feasibility, weather conditions, and vessels and equipment availability. Use of an ROV to conduct 'real time' monitoring of the installation as it occurs would minimize the uncertainty associated with new cables having suspension and/or exposure problems similar to the original cable installation. In recent years, this technique has been effective in producing successful cable installations off Oregon and California.

Remediation that maximizes the likelihood of successful operations would result in cables that are at minimal risk of external aggression. Under this alternative, the susceptibility of cables to external aggression and risk of a cable fault is dramatically reduced in comparison to the status quo, as is the risk that fault repair operations in the future will disturb the sanctuary's natural resources.

7.7 Complete Recovery and Reinstallation with Surface-Laid Cable (Alternative 7)

Alternative 7 is the complete recovery of the existing PC-1 cables in OCNMS and reinstallation by surface lay using a heavier armored cable on the seabed along the existing or similar routes. Under this alternative, a single armor heavy or double armor cable would be used and left unburied on the surface of the seabed. Surface lay of heavily armored replacement cables would reduce environmental impact during the initial installation, but the unburied cable could cause continuing impacts to the seafloor and associated organisms, pose a risk of fishing gear loss and vessel and crew safety, and remain at some risk of fault due to external aggression. Under this alternative, NOAA would amend the current Permit or issue a new permit to the cable owner.

7.7.1 Description of the Methodology (Alternative 7)

From an engineering perspective, Alternative 7 would be relatively uncomplicated to complete. Existing cables would be cut and recovered from the entire route through OCNMS as in Alternative 6, a more heavily armored cable would be spliced in, and the cable laid out on the seafloor for the length of the existing or a similar route through the sanctuary. Plow or jetting burial of the cables in OCNMS would not be necessary. More details on this methodology are provided under other remediation alternatives.

7.7.2 Impacts to Natural Resources and Seafloor (Alternative 7)

Impacts to the seabed and natural resources from cable recovery are described in Section 6.4. Because no disruption of the seabed would be necessary for burial of newly installed cable, the environmental impacts of reinstallation under Alternative 7 would be less than Alternative 6. There would be a minimal amount of lateral movement (0.5 to 1.0 m) of the cable along the seabed during the surface lay installation. The post-installation impacts to the seafloor from

movement of surface-laid cables could occur, yet their magnitude would be difficult to predict. This impact would likely be confined to disturbance of sessile organisms from the movement of the cable on the seabed. Any movement due to currents of the surface-laid cable could result in persistent impacts to nearby sessile organisms. If installation problems are observed by an ROV following the cable installation, such as cable laying over a shipwreck, sections of the cables might need to be lifted off the seabed and re-laid, which would cause environmental impacts in adjacent areas. Loss of fishing gear on the cable could result in ghost fishing impacts and creation of an obstruction that could lead to further gear loss.

7.7.3 Socio-economic Impacts (Alternative 7)

Unburied cables on the seafloor present a hazard to bottom contact fishers for vessel and crew safety and gear loss, although this hazard is considerably less if cables have no areas of suspension above the seafloor. Risk of entanglement and gear loss and potential liability for damage to submarine cables would cause fishers to avoid operations in the vicinity of surface-laid cables. Tribal fishers would be excluded from fully accessing their treaty guaranteed fishing grounds. Because the full length of PC-1 cable routes in OCNMS would have unburied cable, fishers would be excluded from operations over a larger area and socio-economic impacts to fishers would be greater under Alternative 7 than under any other alternative.

7.7.4 Estimated Area Affected (Alternative 7)

The area impacted by cable removal is estimated in Section 7.6.2 at roughly 105,000 m² (0.1 km²). With surface lay of a heavier armored cable, the path affected during new cable installation would be roughly 0.5 to 1.0 m wide along the replacement route, allowing for some lateral movement of the cable during installation. The total area of natural resource impacts by remedial actions under Alternative 7 would be roughly 0.15 to 0.2 km². After installation, the unburied cable could impact the seafloor over the area it moves when subject to seafloor currents or when it is pulled by snagged fishing gear, roughly 0.1 m X 105 km or 0.01 km².

7.7.5 Risks and Uncertainties (Alternative 7)

This alternative would minimize engineering risks associated with multiple cut and splice repair locations (i.e., signal degradation) and reduce the risk of cable fault due to external aggression by using a heavy armored cable. Any surface-laid cable, however, is susceptible to damage from bottom trawling gear. Heavy armored cables are used in areas where bottom contact fisheries occur, but they are typically used where fishing gear is relatively small and light, and where sediments are very soft and the heavy cables can sink below the sediment surface under their own weight (Mike Wilson, PICC, personal communication). Although heavier armored cables are capable of withstanding more external aggression than the existing LWA cables, surface-laid cables are more susceptible to physical damage than properly installed LWA cables buried to 0.6 m below the seabed. Under Alternative 7, whereas the security of the cable systems would be improved over the status quo, the unburied cables would continue to present a threat of fishing gear loss and a safety threat to fishers that can snag gear on the exposed cables, although the elimination of suspensions would reduce this threat substantially. Consequently, surface lay of heavy armored cable could entail a recommendation that the PC-1 cable routes should be avoided by trawlers and long line fishers. Such an agreement would need to be reached between the cable

owners and fishers, and a demand by fishers for compensation for lost opportunity would be likely.

7.8 Management Actions Until Fault, then Complete Recovery and Reinstallation of Buried Cable (Alternative 8)

Although described as an individual remediation alternative, this alternative combines features of Alternative 1 (No Action) and Alternative 6 (Complete Recovery and Reinstallation of Buried Cable). Under this alternative, PC-1 cables would be left as currently installed until a fault occurs, with management measures implemented to mitigate ongoing impacts. When a repair is required, remedial operations would be initiated, and the entire cable within OCNMS replaced with LWA cable buried to at least 0.6 m along the same or a similar route through OCNMS. In the interim before cable reinstallation, this alternative would not address ongoing disturbance to sanctuary resources, impacts on U&A treaty fishing rights, or the risks to fishers. Under this alternative, NOAA would amend the current Permit or issue a new permit to the cable owner, which would include several measures to mitigate ongoing environmental and socio-economic impacts and risks.

7.8.1 Description of the Methodology (Alternative 8)

There would be no remediation activities conducted on the cables until a fault occurs. Under this alternative, management measures incorporated into a new or amended permit could include establishment of a fishers' cable organization, implementation of a no-trawl area(s), and/or financial compensation to fishers for loss of area use. Upon detection of a fault, complete recovery and replacement of the cable within OCNMS would be scheduled by the cable owners, presumably as soon as possible after mobilization of cable installation and ROV-follow vessels, cables, and other necessary equipment. A description of the methodology for complete reinstallation with burial is provided in Section 7.6.1. NOAA would require replacement of both cables when the first fault occurred in the sanctuary.

7.8.2 Impacts to Natural Resources and Seafloor (Alternative 8)

There are two main components to the environmental consequences and uncertainties under Alternative 8. Initially, there would be persistent environmental consequences of leaving the cables as installed in OCNMS with exposures and suspensions until a fault occurs (see Section 7.1.2). Environmental consequences that exist due to PC-1 cables in their current condition include continual impacts to the seafloor and associated biota from strumming of unburied and suspended cable, potential for ghost fishing from gear snagged on the cables, and potential for entanglement of marine mammals. In addition, there would be the environmental consequences of the remedial actions themselves, which are deferred to an undetermined time in the future when repairs are required (see Section 6.4).

7.8.3 Socio-economic Impacts (Alternative 8)

Initial socio-economic impacts under Alternative 8 are those described for Alternative 1 (Section 7.1.3) until remedial actions are implemented, after which they would be those of Alternative 6 (Section 7.6.3).

7.8.4 Estimated Area Affected (Alternative 8)

The area affected by Alternative 8 would be similar to the combined areas affected described for Alternative 1 for ongoing impacts and Alternative 6 for impacts of remedial actions. A gross estimate of the area of sanctuary seafloor disturbed by unburied cable is between 70 and 720 m² (see Section 7.1.4). The cumulative area disturbed by complete reinstallation of both PC-1 cables in OCNMS would be roughly 0.3 to 0.6 km² (see Section 7.6.4).

7.8.5 Risks and Uncertainties (Alternative 8)

Cable engineering considerations and risks are the same as those described for Alternative 1 in Section 7.1.5 and Alternative 6 in Section 7.6.5, and briefly reviewed here. Under Alternative 8 remediation actions would occur in response to a fault; they would not be planned and scheduled in a manner that maximizes the likelihood of successful operations. Under such an emergency repair or remedial response, less consideration might be given to 1) evaluating whether an alternate route holds a higher probability of successful burial, 2) waiting for optimal weather conditions, and 3) selecting the optimal vessels, equipment and crew for the work. When a fault occurs, the cable owner likely will want to mobilize as soon as possible to restore cable service. Unfortunately, the outer coast of Washington is frequently subject to inclement weather and severe storms that generate waves and swell of sufficient size to compromise the operations of even the largest cable installation vessels, particularly during winter months. In fact, such conditions were encountered during the installation of the PC-1 cables in OCNMS when the crew had difficulties in rough seas with control of residual tension on the cable, which compromised cable burial to ≥ 0.6 m depth (ERM 2002). Also, under an emergency repair scenario, the vessels, equipment (including the plow), and crew would likely be recruited from those available locally, as influenced by time and cost of mobilization considerations, rather than the best choices to maximize the success of operations. Thus, for an unscheduled, emergency remediation operation, there is uncertainty for the cable owner associated with the ability to restore cable service in a timely fashion, as well as uncertainty concerning weather conditions suitable for a repair operation and the local availability of vessels, equipment, and crew to maximize the effectiveness of operations and minimize the risk of future failure(s).

8.0 ANALYSIS OF ALTERNATIVES

The purpose and needs of NOAA and OCNMS for this remediation analysis are outlined above in Section 1.0. In brief, the desired outcomes of remedial actions are to minimize disturbance to the seafloor and natural resources in the sanctuary, to achieve the objectives of the terms and conditions in the NMSP permit (OCNMS-01-99), to safeguard and protect the Makah Tribe's treaty rights, to minimize user conflicts in the vicinity of the PC-1 cables, and to reduce risks to the safety of fishers. In this process, NOAA seeks to develop alternatives that maximize the effectiveness of remedial actions, are technically feasible, and have minimal risk and uncertainties associated with the remedial actions. NOAA believes that the analysis provided in this document is based on the best available technical review and scientific understanding of the environmental and cable conditions along the cable routes. This analysis is based on reviews by

marine biology, marine geology and cable engineering experts and, in many instances, supported by documentation and analyses provided by the permittee's reports and analyses.

This analysis considered that there is incomplete data on cable burial. Decision criteria are applied to evaluate the comparative risk and benefit of each alternative to clearly illustrate the selection process.

8.1 Analysis of Risk to Cables, Fishers and Natural Resources

NOAA's analysis leads to the conclusion that the cable, fishers and natural resources are at risk from the current status of the PC cable, as discussed below.

8.1.1 Unknown Cable Burial Condition

There are large areas of the cable routes where there are no reliable data to characterize cable burial depth. In sum, cable burial depth is unknown for about 13 km (11%) of the cable routes in OCNMS where TSS data have not been collected. Primarily due to widespread high residual tension applied to cables during installation, the logged plow penetration depth provided by plow instruments is a poor indicator of achieved cable burial depth. The application of PC-1 North cable burial conditions to those of PC-1 East or vice versa to fill data gaps is not appropriate because the cables were laid six months apart, under different sea state conditions, and likely by different installation staff. Also, the routes are sufficiently distant from one another that the substrate can and does differ along the routes. NOAA concludes that the risk to cables from interactions with fishing gear, the risks to fishers, and the risks to natural resources cannot be assumed to be zero where cable burial depth data have not been collected.

8.1.2 Burial Depth That Represents Low Risk

Although characterization of low risk of external aggression or cable fault is to some degree a subjective exercise, the industry standard at the time of installation, which NOAA adopted for these installations, was to bury cables to at least 0.6 m depth to avoid contact with bottom trawl gear. The current industry standard is ≥ 1.0 m. Burial depth of less than 0.6 m does not meet NOAA's nor the industry's standard for low risk. To define cable burial depth to minimize risk, several factors must be considered, including depth of penetration for fishing gear used in the area, sediment mobility, sediment type, accuracy of burial depth measurement, and a safety factor. NOAA maintains that the permit condition for burial to at least 0.6 m reflects a reasonable and widely accepted measure of low risk to cables, fishers and natural resources. This is affirmed by the more protective, current international standard for submarine cable burial to ≥ 1.0 m in areas where bottom trawling occurs.

8.1.3 Cable Suspended Atop or Deflected By Boulders

Where the cable is suspended over or deflected by a hard object such as a boulder, the risk of physical damage to the cable is elevated as a result of increased potential for localized stress, metal fatigue, and armoring damage, even if the current risk from trawling is low at that location. A review of video interpretation from the RCBAR (ERM 2002) and OCNMS videos revealed at least 24 locations where cable was suspended atop or in contact with boulders. These locations

are widespread on the cable routes. Suspensions also potentially cause natural resource damage through ghost fishing and gear entanglement. If suspensions occur in areas of fishing activity, the suspended cable poses a risk to fishers. NOAA concludes that areas of cable suspension, and particularly suspensions associated with hard substrate, are at greater risk of fault regardless of the level of fishing activity in the area.

8.1.4 Fishing Effort Changes Over Time

Bottom trawling is allowed in the sanctuary. Whereas data are available to characterize recent non-tribal fishing effort, future fishing effort cannot be definitively anticipated in terms of areas fished, number of trawls conducted, and design of the gear used. Fishing effort by tribal vessels was not characterized in this document because data were not made available. Tribal bottom trawlers are not subject to depth-based closures that have recently been imposed on non-tribal West Coast trawlers. Moreover, exclusion of Tribal fishermen from their U&A fishing grounds would cause more than a de minimis impact to their right of access. As a result, areas of shallow cable burial or unburied cable cannot be characterized as low risk of fault over the 25 year life expectancy of the cable nor for the extended future, and remediation of these areas cannot be avoided solely because non-tribal fishing does not occur there currently. In addition, in some areas that are currently considered not fished or areas of low effort, trawl tracks observed by NOAA near or on the cable routes indicate recent fishing activity.

8.1.5 Widespread Occurrence of Cable Concerns

The PC-1 cables in OCNMS currently show widespread evidence of exposure to external aggression, and cable faults have occurred on the PC-1 cables to the west of OCNMS in Canadian waters. NOAA has observed evidence of fishing gear in the vicinity of the PC-1 cables, cable suspended and deflected by boulders, strumming cable at suspensions, fraying cable serving where the cable contacts boulders, and trawl tracks in areas of shallow or unburied cable. These widespread occurrences include evidence of external aggression in all the large areas of concern defined by NOAA and the RCBAR. The existing evidence of external aggression to PC-1 cables in OCNMS leads NOAA to believe that cable faults within OCNMS are inevitable, adding urgency to its belief that remediation must occur.

8.2 Implications for Selection of Remediation Options

8.2.1 Remediation Approaches Are Limited

Although NOAA does not oppose using a combination of remediation techniques, remediation through a site-specific approach or multiple small projects is not considered a reasonable approach due to the widespread distribution, broad extent, and varying types of problems along the PC-1 cables in OCNMS. A site-specific remediation approach could require a variety of techniques (e.g., rock dumping, jetting, cut and splice) that are best applied to relatively small problem areas. In sum, this approach could result in a several cable bights, multiple jetting/PLIB operations, and high mobilization expenses for different technologies. Costs for mobilization of rock dumping equipment and production of the required material are likely extremely high, which makes it impractical to apply this technology for small areas. If rock dumping were widely applied, the associated habitat alteration and direct mortality to sanctuary resources over large

areas would be proportionally greater than for other alternatives. Although it might be possible to mobilize a single ship with the capability to apply multiple technologies, NOAA seeks to ensure the repairs are done properly, under conditions that do not potentially compromise effectiveness of operations, and the results are fully examined for compliance.

NOAA concludes that there are three large areas in OCNMS of cable burial $<0.6\text{m}$ on each PC-1 cable, and the status of the cable in some others areas is uncertain. For this reason, technologies that address repairs on a scale of several kilometers of cable route are required.

8.2.2 Evidence for Suitability of Substrate for Burial

Evidence of a visible plow trench over extensive areas where cable burial to $\geq 0.6\text{ m}$ was not achieved indicates that the substrate was suitable for burial in many of these areas, with the implication that shallow burial or unburied cable resulted from factors other than the substrate. Two marine geologists who reviewed geotechnical data and cable route videos concluded that a substantially greater amount of the cables could have been buried to $\geq 0.6\text{ m}$ along the selected routes. In limited areas, substrate, such as large boulders and subsurface conditions that were not detected in route planning surveys due to the technologies and level of effort applied, did prevent effective burial with the plow. In some areas, minor re-routes could have avoided substrates and slopes that may have caused problems achieving cable burial to $\geq 0.6\text{ m}$.

From this analysis NOAA concludes that, as indicated in permit application materials, pre-permitting discussions and the resulting SEA, the cables could have been more effectively buried throughout the sanctuary with the equipment used during installation, and that factors other than substrate conditions led to cables being unburied, suspended, and shallowly buried at many locations. Thus, cable reinstallation using a plow could result in cable burial substantially improved over the existing condition.

8.2.3 Problems with Residual Tension on Cables

High residual tension in the cables was a persistent operational condition during the PC-1 installations that led to widespread shallow burial and suspended cables in OCNMS. This tension remains 'locked' into the cables and limits remediation options. Because the cables are under tension, jetting for retroburial will be far less effective for removing suspensions at many locations, and jetting will not be effective for increasing burial depth. Jetting will only be effective at locations where two conditions are present: 1) sizeable soft seafloor features can be reduced or liquefied by jetting, and 2) residual tension is low. High residual tension might make rock dumping a risky alternative in areas of suspension greater than a few centimeters off the seafloor due to the potential for damage to the cable. Unfortunately, there is no existing technology for measuring residual tension of installed submarine cables to determine where jetting or rock dumping might be effective and practical.

Because of widespread high residual tension, NOAA concludes that there are few locations where jetting might be effective, unless jetting is used in conjunction with another approach, such as splicing or reinstallation. High tension in areas of suspension also may limit areas in which rock

dumping would be feasible, though NOAA would only consider this alternative for small areas because of alteration to the habitat.

8.2.4 Additional Route Survey Data May Be Needed for Application of Some Remediation Alternatives

Local slopes can be much greater than indicated in available databases because these slope values were calculated with averaging over distance. For analysis of remediation approaches, uncertainty about localized slope data has implications on the effectiveness of rock dumping for cable protection, as well as for localized re-routing to avoid steep slopes that preclude effective cable burial. Sub-bottom data are not available except where soft sediments occur because the operational frequency of the sub-bottom profiler used during the route survey was not sufficient to penetrate hard substrates, such as gravel and cobble. Without further survey work, the feasibility of plow burial remains uncertain in areas because the nature of the subsurface material is not known. The evidence of a trench does indicate that the substrate was suitable for burial in many areas where effective burial was not achieved; however, additional sub-bottom data would be advantageous for application of most remediation alternatives. In addition, higher resolution side scan sonar data should be used for any cable rerouting to identify and avoid boulders that would prevent plow burial.

NOAA concludes that additional geophysical data should be collected, depending on the remediation alternative implemented. The cables can be buried to a much greater extent in the sanctuary along their existing routes without these data, but additional geophysical data will maximize the extent of cable burial to permit specifications.

8.3 Decision Criteria

Each of the decision criteria used to evaluate the remediation alternatives are discussed below.

8.3.1 Technical Feasibility

A fundamental consideration made during NOAA's evaluation of remediation alternatives is the technical feasibility and probable success of remedial actions. NOAA acknowledges that with the implementation of any of the remediation alternatives, complete burial throughout the sanctuary to ≥ 0.6 m depth might not be achieved but that more effective burial can be achieved. Some approaches identified in remediation alternatives are technically feasible but impractical because of risk to the equipment, unsuitability for application to the number or scale of problem areas, potential impacts to cable system integrity, or minimal anticipated improvement of cable burial condition. Approaches that defer remediation actions until a fault occurs have a lower technical feasibility because they incorporate risk that expedited or emergency mobilization efforts and inclement weather will not provide optimal equipment or conditions to maximize the effectiveness of operations.

8.3.2 Ongoing and Future Seafloor Disturbance

Another important consideration for NOAA is the type, timing, and duration of disturbance to the sanctuary seafloor habitats and biological communities, as described in Section 7.0. The project

was proposed as a one-time disturbance along each cable route, with very high probability of successful cable burial and very low probability of future disturbance for repair activity. NOAA anticipated that the majority of the cable would be plow buried with ROV jetting, a more disruptive burial technique, necessary only in areas of cable crossings. NOAA also anticipated that seafloor disturbance of cable installation would be followed by a period of recovery, and it initiated a monitoring program to document recovery of the seafloor habitat and biological community along the cable routes. The project as built did not achieve consistent cable burial to ≥ 0.6 m depth, and consequently, the risk of future faults and seafloor disturbance is higher than it could have been on these routes that traverse a national marine sanctuary. NOAA is concerned because the current condition of the PC-1 cables causes continuous, ongoing impacts and substantially elevates the potential for future cable repair operations and thus, recurring disturbance to the seafloor of the sanctuary. Disturbance could occur at multiple locations and could leave the sanctuary seafloor along the cable routes in a continual state of disturbance and recovery during the anticipated 25-year service life of the cable system. Each conventional repair activity requires jetting to rebury the cable, which would impact previously undisturbed habitat in the area of the bight as well as the area along the cable route. Therefore, NOAA's consideration of remediation alternatives places lesser importance on the cumulative area of immediate or one time impact, and greater importance on the repeated nature, type and timing of disturbance, as well as other factors, such as whether bights are required, the risk to fishing vessels, and loss of fishing opportunity within tribal U&A grounds. Whereas remediation of the existing cable would cause disturbance to the seafloor, a one-time disturbance followed by recovery is considered less disruptive and more consistent with NOAA mandates than the ongoing and potentially recurring disturbance. Consequently, remedial actions that involve a persistent elevated risk of cable fault are considered undesirable, and remedial actions that substantially reduce the risk of future seafloor disturbance are sought, even if their immediate impacts are greater than no action or partial repair efforts. This prioritization is more consistent with NOAA's responsibilities as a natural resource trustee, as well as with its legal obligations and treaty responsibilities to the Makah Tribe.

An additional consideration is that PC-1 cables are installed in a publicly owned and protected marine area. The commercial venture should be held responsible for meeting the objectives of the Permit to minimize ongoing and future impacts to public natural resources and area users.

8.3.3 Achieving Existing Permit Objectives

Permit conditions that required cable burial wherever possible were intended to minimize the risk of repeated seafloor disturbance, to meet OCNMS' mandate for protection of natural resources of the sanctuary, and to minimize user conflicts. Remediation alternatives that leave substantial portions of the cables poorly protected from external aggression do not substantially reduce the risk of future disturbance and might not reduce ongoing disturbance to natural resources. Remediation actions that substantially change the nature of the seafloor (e.g., protective rock cover, powerful jetting) would not achieve permit objectives and sanctuary mandates. Permit objectives are not being met if commercial fishers and tribal fishers are restricted from full access to traditional trawling grounds and treaty guaranteed U&A fishing grounds.

8.3.4 Safety Risks to Fishers

Where cables are unburied and suspended, fishers risk gear loss and also risk the safety of their crew and vessels should heavy gear become entangled with a submarine cable. A trawling vessel snagged on a cable is tethered by a heavy steel cable running off its stern, which makes it extremely vulnerable to capsizing or flooding in rough seas. This risk persists under any remediation alternative that fails to remediate unburied and suspended cable.

8.3.5 Impacts to Tribal Treaty Rights

The federal government has a legal obligation as well as a fiduciary responsibility to safeguard and protect treaty rights guaranteed to Makah Tribe in the Treaty of Neah Bay and Klallam tribes in the Treaty of Point-No-Point, including access to their U&A fishing grounds. Any activity or condition that has adverse impacts on the fishery resources in their U&A fishing grounds or limits the area in which tribal fishers can safely operate without risk of snagging or losing gear will impact the Tribe. The Makah Tribal Council has expressed strong concerns about current and future impacts of the cables on Tribal fisheries (Tyler 2003). Specifically, Makah fishers consider that unburied cable poses a serious risk of entanglement for fishing gear and a safety risk to vessels and crew. Furthermore, Makah longline fishermen have reported to their fishery managers gear loss due to encounters with the cable, and bottom trawlers have reported gear snagged on the cable. This area-use restriction reduces the ability of Makah fishers to succeed economically in what has long been a challenging business that contributes significantly to the economy of their remote community. Moreover, this present condition is causing more than a de minimis impact to the Makah's treaty right of access to their U&A grounds and stations. Consequently, the Makah Tribe and NOAA prefer remediation alternatives that are sufficient to ensure the Tribe's access to all its U&A fishing grounds, alternatives that substantially improve the situation from the status quo and result in buried cable meeting or exceeding the depths defined in the Permit.

8.3.6 Socioeconomic Impacts and Multiple Use of the Sanctuary

Analysis of remediation alternatives must include consideration of socioeconomic impacts. The fishing industry has suffered economic impacts with reduced quotas and restrictions on areas fished, all of which were implemented to protect the fishery resources. Access restrictions due to cable condition put an undue burden on fishers that are already under considerable pressure from reduced opportunity. NOAA contends that submarine cables and fishers can coexist in the sanctuary, and socioeconomic impacts on fishers can be minimized with appropriate remediation of the existing cables.

8.3.7 Risk of Future Cable Faults

Minimizing the risk of future cable faults is critical to NOAA due to the habitat and natural resource impacts caused by repairs. NOAA has strong concerns that large-scale seafloor disturbance may occur repeatedly, over an extended period of time as repeated repair operations are required to maintain cable integrity. Disturbance from repairs results from cable recovery, the addition of a bight and subsequent PLIB operations along the bight in areas beyond the original cable route. In sum, the length of disturbed seafloor from recovered and spliced cable could add

up to roughly 4 to 5 times the water depth at the site, and more if an ROV is not available and grapnels are used to cut and recover cables. Such cable repair operations can disrupt the sediment stratigraphy (layering) by mixing sediment layers in a hydrolyzed blend, alter the physical composition of the substrate, and physically damage epifaunal (i.e., living on the surface) and infaunal (i.e., living in the sediment) organisms. The power and capabilities of the ROV jetting device can also influence the amount of disturbance caused, with a high powered vacuum ROV jetting device having the potential to cause substantially more disturbance than an ROV jetting device similar to that used in the original installation. Regardless, jetting of any type causes greater disturbance than plow installation.

8.4 Comparative Risks and Benefits

The application of the decision criteria showing the comparative risks and benefits of each remediation alternative are summarized in Table 2. This comparison uses the status quo condition as the baseline and evaluates whether each remediation alternative improves or worsens the existing condition. A brief summary of NOAA's position on each alternative follows.

Alternative 1 (No Action) requires emergency repair operations when a fault occurs, during which rough seas and lack of availability of optimal equipment, vessels, and crews to perform the repairs could compromise optimal cable burial. This alternative is unacceptable to NOAA because it does not adequately address safety risks to fishers, is inconsistent with Native American treaty rights, and would not achieve permit objectives. It allows for continuous disturbance to the sanctuary seafloor, adverse impacts to natural resources and fishers, as well as sustained risk of future damage to sanctuary resources potentially resulting from multiple repair operations.

Alternative 2 (Reduction of Selected Suspensions Without Splicing) provides for limited repair of cable in areas with the greatest potential for user conflicts or the most susceptible to external aggression and cable fault. Remedial actions under this alternative are technically impracticable at some locations, have limited probability of success, and accomplish relatively little to reduce persistent impacts to sanctuary resources, the risk of cable faults requiring repair in the future, and area use conflicts, including vessel safety and treaty rights. This alternative does not meet the permit objectives and allows for continued disturbance to the seafloor and benthic communities, as well as the potential for ghost fishing and entanglement. Lowering the highest suspensions may be possible but eliminating them is highly unlikely due to the residual tension on the cable and the size of some obstructions.

Alternative 3 (Protective Rock Cover) could substantially reduce the risk of future cable faults caused by external aggression, but extensive portions of the cable route would require rock cover to achieve permit objectives. Habitat alteration at that scale is not acceptable to NOAA. This alternative appears to be best applied to relatively small problem areas and in combination with other technologies. Application of this alternative in any form would require analysis of its effectiveness for long-term protection under various site conditions, the routes for feasibility of application, its compatibility with treaty fisheries conducted in the area, and the environmental consequences associated with habitat alteration.

Alternative 4 (Repair by Splicing and Cable Retroburial) would be impractical to implement because the number and widespread distribution of problem areas on the cable routes cannot be addressed by cut and splice repair techniques targeting multiple sites. From an engineering perspective, this approach is infeasible because the multiple repair points and added length of cable could cause signal degradation without significant reduction in the risk of cable fault.

Alternative 5 (Repair of Large Problem Areas) is technically feasible and could substantially reduce the extent of suspended, unburied, and shallow buried cable while avoiding complete reinstallation of the cables in the sanctuary. Ongoing impacts to sanctuary natural resources, risk of cable fault, and conflicts with fishers, including Tribal fishers, could be reduced if remedial actions were successful in achieving cable burial to ≥ 0.6 m depth. Potential areas of shallow burial at a minimum of 8 PLIB sites within the sanctuary could result and present area-use conflicts with fishers, including Makah fishers. As a result, this alternative is less certain to protect both treaty rights and natural resources than is Alternative 6 (Complete Recovery and Reinstallation with Cable Burial).

Alternative 6 (Complete Recovery and Reinstallation with Cable Burial) is NOAA's Preferred Alternative and ACOE's Proposed Alternative because it is technically feasible, and it has the greatest potential to meet the permit objectives, reduce risks to sanctuary resources, and minimize conflicts on Makah treaty rights. It provides that cable reinstallation could be planned and implemented in a manner that minimizes the risks and uncertainties of remediation success associated with route selection for optimal burial feasibility, weather conditions, and vessel and equipment availability. The cable owner (Pacific Crossing Ltd. or PCL) and the contractor for the cable's original installation (Tyco Telecommunication (US) Inc. or Tyco) have indicated that they will accomplish the cable remediation based on a remediation protocol and plan that would implement NOAA's Preferred Alternative and the ACOE's Proposed Alternative. Under this alternative, it is expected that ongoing impacts to sanctuary resources from shallow buried, unburied and suspended cables would be substantially reduced, if not eliminated, along with area use conflicts. Furthermore, the susceptibility of cables to external aggression and risk of a cable fault would be dramatically reduced in comparison to the status quo, as would be the risk that fault repair operations in the future will disturb the sanctuary's natural resources. This alternative also results in a one time disturbance rather than continuous or recurring disturbance to the seafloor and benthic communities.

Remediation Alternative 7 (Complete Recovery and Reinstallation with Surface-Laid Cable) is technically feasible and has minimal initial impact on seafloor resources, but it would leave unburied cables across the sanctuary where they would be susceptible to external aggression in areas where current and future fishing effort is focused. Application of this alternative would allow for persistent disturbance to the seafloor and create user conflicts for both tribal and non-tribal fishers. Avoidance of unburied cable would limit access of tribal members to their U&A fishing grounds. This alternative does not meet the Permit objectives.

Remediation Alternative 8 (Management Actions Until Fault, then Complete Recovery and Reinstallation with Cable Burial) would leave the PC-1 cables in their current condition for an indeterminate period, during which they cause persistent impacts to sanctuary natural resources and conflicts with area users. This alternative conflicts with tribal treaty rights and perpetuates the safety risk to fishers trawling in the vicinity of the cables. Because the timing of repair

activities would be dictated by the occurrence of a cable fault, the effectiveness of cable burial during an emergency-driven reinstallation would be less certain than with the planned and scheduled reinstallation provided under Alternatives 5 and 6. This alternative does not meet the objectives of the Permit as well as either Alternative 5 or 6 because it allows for ongoing adverse impacts until remediation occurs.

With the exception of the Alternatives 5 (Repair of Large Problem Areas) and 6 (Complete Recovery and Reinstallation with Cable Burial), all remediation alternatives to some extent would leave the PC-1 cables in OCNMS suspended, unburied, or shallow buried in areas, where cables are at increased risk of fault in the future. Moreover, these conditions cause persistent disturbance to the sanctuary seafloor and impacts to natural resources, conflict with Tribal treaty rights, and area use conflicts and increased safety risks to fishers.

Table 2. Matrix to compare the eight potential remediation alternatives using eight decision criteria

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
Decision Factors	No Action	Reduction of Selected Suspensions without Splicing	Protective Rock Cover	Repair by Splicing and Cable Burial	Repair of Large Problem Areas	Complete Recovery and Reinstallation with Cable Burial (Preferred)	Complete Recovery and Reinstallation with Surface-laid Cable	Management Actions Until Fault, then Complete Recovery and Reinstallation with Cable Burial
1. Technical feasibility	○	⊙	?	⊙	○	○	○	○
2. Ongoing natural resource impacts	⊙	●	⊙	○	●	●	●	○*
3. Future seafloor disturbance	⊙	●	●	○	●	●	●	○*
4. Achieving existing Permit objectives	○	○	●	○	●	●	●	○*
5. Safety risks to fishers	○	○	●	○	●	●	●	○*
6.. Impacts to tribal treaty rights	○	○	●	○	●	●	○	○*
7. Socioeconomics	○	○	●	○	●	●	○	○*
8. Risk of future cable faults	○	●	●	○	●	●	●	○*

*Note: Considering decision factors 2-8 with respect to Alternative 8, the condition is expected to be the same as the no action alternative until there is a fault. After remedial actions, the condition is expected to improve comparable to Alternative 6.

- Substantial improvement over status quo
- ⊙ Negative impacts in future or is impracticable
- Partial improvement over status quo
- Same as status quo (i.e., no change) or is practicable
- ? Uncertain

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